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Professional Development: A Case Study of Mrs. G

Sharilyn Kay Owens
University of Tennessee - Knoxville, sgranade@utk.edu

To the Graduate Council:

I am submitting herewith a dissertation written by Sharilyn Kay Owens entitled "Professional Development: A Case Study of Mrs. G." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Vena Long, Major Professor

We have read this dissertation and recommend its acceptance:

Charles Collins, Lynn Hodge, Blanche O'Bannon

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Sharilyn K. Owens
May 2010

Dedication

Dedicated to my loving family: Randy, JD, Emily, Mom, Dad, Debbie, Greg, Thomas, Elizabeth, Zeb and Beulah.

Acknowledgements

I am grateful to my loving husband, Randy Gambill. For the duration of our courtship, engagement and marriage, I have been a doctoral student with my time monopolized by study and dissertation. My musician husband has been very patient with me as I attended every gig with my head in a book and laptop in hand. He believes in me.

My children, James Douglas Granade (17) and Emily Granade (16) have made many sacrifices along the way. They had just completed the sixth and fourth grades respectively when we began this journey together. They endured three summers being farmed out to camps and family while I attended summer sessions with ACCLAIM. They have been very brave and supportive as their mom has made some unpopular choices. I have missed games and performances and volunteer opportunities due to my studies. They have never complained. Even as children, they recognize the importance of achieving and even greater importance of becoming.

I have been a student during my entire relationship with my step-children Zeb and Beulah Gambill (both 21). They have eaten many meals atop piles of data at our kitchen table. I was unable to attend their high school graduation because of a conflict with classes. They have embraced me and my studies.

My parents, Dr. Douglas and Mrs. Faye Owens, have always encouraged me to be my best self. Both of my parents read my dissertation many, many times, brainstorming, making suggestions and corrections. They encouraged me through numerous tearful,

dark nights. Their simple reminders of, “You can do it! It’s the kind of stuff we’re made of!” have lighted my way through fractious times. The seeds of faith they planted are a replenishing garden that sustain me.

My parents are also involved in my professional life. My mom first introduced me to the Appalachian Collaborative Center for Learning, Instruction, and Assessment in Mathematics (ACCLAIM) program in San Antonio. Knowing that lack of proximity to a university with a PhD program was hindering my opportunity for higher education, she was conversing with members of the ACCLAIM management team. I remember her very words waving me over from across the reception hall: Get over here! This is a program you can do! I am grateful to my dad who included me in the CCMS project from the first summer institute and to Dr. Stephen Pape who enthusiastically welcomed me to the qualitative research team. I appreciate the other principal investigators, Dr. Louis Abrahamson and Dr. Karen Irving who also welcomed me aboard. As a student with much to learn from them, I was treated as a colleague and a valued member of the team. Many thanks to Dr. Clare Bell, who spent hours poring over transcripts with me for the purpose of peer checking, but also with genuine interest in my study and our profession.

Mrs. G has been a professional and personal support. I regret that due to the restrictions in place before I chose this study, she shall remain anonymous. She allowed my frequent visits her classroom, even when it was clearly not convenient for her. She has rearranged her schedule on my behalf many times. She is a professional inspiration to me. She represents the practitioners whose enthusiasm has never been dampened by the daily struggle to reach students, even in adverse circumstances. She motivates me to be a life-long learner.

I can never say enough to thank the ACCLAIM management team and professors. Without this distance program for rural Appalachian teachers, I would not have been able to pursue my dream of higher education. Through the ACCLAIM program I have received much more than an education and a degree. I have had life changing experiences as promised when I prepared for my first summer of "math camp," as we endearingly called it. I remember reading about self-actualization for the first time in readings for my first summer session and thinking, "this is what I am going to do- find out who I am supposed to be in this world and negotiate that path."

Thanks to Dr. Vena Long, my dissertation committee chair and PI for ACCLAIM. On a personal level, she has encouraged me since my first summer away from my children. She has reminded me that "women don't do things late, we do things in different order!" Although there have been disappointments, Dr. Long has always had my best interest at heart. She has never doubted that I would finish this program and has prompted me to "hang tough" during many fragile times.

I am grateful to the members of my committee, Dr. Charles Collins, Dr. Lynn Hodge and Dr. Blanche O'Bannon. These dedicated professionals agreed to be on my committee, even though, as a distance learner, they did not know me, nor did they receive any professional credit for the load of an extra dissertation.

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ABSTRACT

This dissertation is a case study of one teacher who participated in a project that investigated the effects of the Texas Instruments Navigator™, a wireless communication system on student algebra achievement and related pedagogy. The larger study, Classroom Connectivity in Promoting Mathematics and Science Achievement (CCMS) based at The Ohio State University (OSU), funded by the U. S. Department of Education, involved approximately 120 self-selected participants across the United States. A partial requirement for participation was agreement to attend professional development provided by the CCMS project. The professional development included a week-long summer institute at OSU prior to implementation of the TI-Navigator™, attendance at annual International T^3 meetings, participation in the cohort listserve, and semi-annual telephone interviews.

During data collection of the CCMS project, many of the participants exhibited an enthusiasm for implementation of the tool and the pedagogy supported by the CCMS project. The subject of this case study, Mrs. G, was among those perceived as high implementers. This longitudinal study attempts to verify alignment of her instruction with the pedagogy promoted in the professional development sessions provided by the project. Transcripts from professional development sessions were compared with Mrs. G's comments about her perception of her implementation of the project. Transcribed classroom observations were then analyzed using NVivo software to quantify evidence of implementation of the pedagogy with respect to the three constructs of classroom discourse, levels of questioning and formative assessment.

The results of the analyses indicated that Mrs. G implemented the pedagogy advocated by the professional development sessions of the CCMS project. According to the literature key elements were in place for successful professional development. The teacher was allowed autonomy and choice in her professional development In Mrs. G's words, "Professional development must be relevant to my profession and support my goals--student understanding." Implications are that pre-service programs should instill in prospective teachers the importance of life-long learning and equip them with strategies to seek out professional development opportunities that are relevant to them. In-service teachers should in turn be given autonomy and choice in determining which professional development opportunities will complement their programs.

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CHAPTER ONE

INTRODUCTION

Statement of Issue

One of the significant concerns regarding education reform today is that the American education system is "always reforming but not always improving," and the most alarming aspect is we have "no mechanism for getting better" (Stigler & Heibert, 1999, p. ix). Professional development is often accredited with promoting teacher change but evidence of success is sketchy at best. However, classrooms exist where goals for teacher change are realized and active student learning is the focus. Studying these environs may highlight strategies that could be replicated in teacher preparation and professional development.

While collecting data for the Classroom Connectivity in Promoting Mathematics and Science Achievement (CCMS) Project based at The Ohio State University, such a case came to light. The CCMS project seeks to use Texas Instruments Navigator™, (TI-Navigator™) wireless system, to open communication between students and teacher in mathematics classrooms, specifically algebra I. A participant whom I observed was excited about the project, open to the new technology and as a result, an enthusiasm for learning was generated in her classroom. This classroom was decidedly different from other classrooms observed.

I made note that although Mrs. G employed questioning techniques in her classroom, the level of questioning seemed to change throughout her time in the CCMS project. Her students seemed to interact with and respond to one another with increased frequency. I also suspected that Mrs. G was using formative assessment to make changes during her lessons to enhance student learning. In our conversations, she made it clear that she was a reflective practitioner. As a former classroom teacher, this raised my curiosity. What compels this experienced, tenured teacher to continue learning about her classroom?

Introduction of the CCMS Project

The CCMS Project is a four-year project funded for three million dollars by the Institute of Educational Sciences (IES)[1], the US Department of Education, and Texas Instruments, Inc. The nation-wide project includes approximately 150 algebra I and physical science teachers of students primarily in grades 7-10. Students of this age are at a critical juncture for learning mathematics and science (CCMS, 2005). This project aims to promote student learning by enhancing classroom practices such as enriched classroom discourse, quality and levels of questioning, self-regulated learning and utilization of formative assessment (CCMS, 2005). Recognizing that simply the presence of new software does not ensure teacher change, the project designers implemented many avenues for reflection and professional development. Clarke (1994), through an analysis of professional development research, gives a framework for effective professional development. The professional development opportunities of the CCMS Project are aligned with this framework.

[1] The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305K050045 to The Ohio State University. The opinions expressed are those of the authors and do not represent views of the U.S. Department of Education.

The participants were self-selected volunteers who became aware of the CCMS project while attending calculator sessions at a National Council of Teachers of Mathematics (NCTM) annual meeting and Teachers Teaching with Technology (T^3) International Conference. Most likely, they are open to employing the latest trends in their classrooms, and, therefore, are a non-representative sample of mathematics teachers.

CCMS Addresses Pedagogical Issues

Recent research in how people learn mathematics focuses on communication. The latest standards from the National Council of Teachers of Mathematics (NCTM) challenge teachers to encourage student discussion and collaboration and create an environment where students share their ideas and explanations (National Council of Teachers of Mathematics, 2000). By doing so, student misconceptions are exposed and corrected in a timely manner. The CCMS project specifically addresses these issues:

> Products of this research promise to aid in mathematics and science conceptual development by improving classroom formative assessment, classroom discourse, self-regulated learning, especially in the quality of questions asked, class discussion, and expose and correct student alternative understandings. For most teachers in typical situations in today's schools, it is extremely challenging … to apply these techniques for most students all of the time. This study proposes to draw teachers from across the nation and guide research in the interaction of pedagogy and technology for promoting greater student achievement. In this proposal, we embed these instructional strategies within social constructivist, social cognitive and conceptual change models of teaching and learning. (Owens et al., 2005, pp. 1-2)

CCMS Proposal Addresses the Pedagogical Issues of Discourse, Levels of Questioning and Formative Assessment

In many traditional classrooms following teacher lecture, students are assigned problems to try on their own. In some cases, working with others or checking answers is considered cheating. The student returns the assignments the next day, and it is graded and passed back to the student. This process may take three class days. By then any students' misconceptions are likely stored in their memories. Furthermore, opportunities to explain their reasoning, and thereby expose their misconceptions, are limited to written work only. The original CCMS proposal asserts that "in connected classrooms, as soon as student work is submitted it is instantly aggregated and available on the teacher's computer. Displays can give powerful clues to what students are doing, thinking and understanding" (Owens et al., 2005, p. 3). Rich opportunities to implement desirable classroom practices are now available. The teacher sees the misconceptions and is able to make immediate adjustments (formative assessment) in lessons to correct them. Additionally, the student in a traditional classroom, who is unwilling to discuss his confusion, sees that other students have faulty ideas, and s/he is now open to talking with his fellow learners and teacher to realign his thinking (Owens et al., 2005, p. 4). In the pilot study, the researchers found

> "what appeared to be a chain of events beginning with students' (a) personal privacy, and public anonymity afforded by the technology, they and the teacher get (b) rapid knowledge of class understanding or misunderstanding, where frequently it is seen that (c) others are having the same difficulties. This opens the way for (d) class discussion where (discourse) (e) reasons for actions taken become more important than who took them. A (f) trust is built in the classroom as student find themselves less embarrassed because they understand that others have similar thoughts or misconceptions, and students learn from the resulting (g) peer interaction. In this increasingly student-centered environment, (h) non-confrontational competition adds interest; often [was] observed (i) cheering and enthusiasm; (j) camaraderie as students and teacher are "on the same side", and (k) pride in the achievements of the class as a whole" (Owens , Demana , Abrahamson, Meagher, & Herman, 2004)

Professional Development Sessions

Recognizing that the mere presence of the new technology likely does not reform the classroom climate, the CCMS Project is committed to extensive professional development sessions. Formal professional development, led by Teachers Teaching with Technology (T^3) instructors, was offered at summer institutes at The Ohio State University (OSU). Since teachers are "generally skeptical of changing their teaching methods," (Owens et al., 2005, p. 12) the CCMS followed the T^3 model of having practicing teachers share their experiences with the technology. "Faculty lectures infused theoretical and pedagogical focus" (Pape, Irving, & Owens, 2008, p. 10) during the summer institutes while introducing the Texas Instruments Navigator™. Sessions were scheduled to directly address learning and teaching theories, but they were limited. The gap between theory and practice was more effectively bridged "through real-life examples of classroom activities, coupled with true stories about actual events" (Owens et al., 2005, p. 12). This follows Vygotsky's Zone of Proximal Development (ZPD) model in which the novice moves to a level of expertise with the assistance of one who is experienced in the field (National Research Council, 2000).

Proposed intervention for the CCMS Project also included professional development sessions preceding T^3 International meetings, followed by opportunity to attend the conference. During the pre-conference professional development sessions, in accordance with the ZPD model, teachers who had been novices during the summer institutes now had opportunities to share what they had learned as they had experience with the new technology during the fall semester of school.

Less formal opportunities for professional development included telephone interviews which, in addition to data collection, served as an opportunity to reflect upon the implementation of the pedagogy. There was also a listserv whereby teacher participants in the CCMS Project could share ideas and concerns among themselves.

Modeling the Pedagogy

The CCMS personnel carefully considered the pedagogy the project was promoting and modeled the importance of quality classroom discourse, varied levels of questioning and the use of formative assessment in the planning and implementation of professional development opportunities. The summer institutes and pre-conference sessions were designed with multi-directional discourse in mind. The teacher participants were seated at round tables, an environment that is conducive to discussion. Participants helped one another grapple with the technology as newcomers to the TI-Navigator™ and brainstormed its usefulness in algebra lessons.

The CCMS proposal aimed for the T^3 instructors, who were teaching the new technology, to use questioning to guide the course of the week-long summer sessions. Rather than strictly telling the participants what kinds of lessons they have taught, the instructors asked the participants to think about appropriate uses of the TI-Navigator™ in their own classrooms. In summary of the week's activities, table teams presented lesson plans they constructed that would use the new technology to implement the desired classroom practices (Owens et al., 2005).

The summer institute included formative assessment in the form of daily debriefings to allow time and opportunity for participants to think about what they had learned and identify possible gaps in their understanding that could be addressed the following day. The professional development sessions were not planned to be prescriptive, but rather to be adjusted on a daily basis to meet the needs of the participants. Reflection and evaluation of learning is a running theme throughout the CCMS Project in accordance with the T^3 program (Owens et al., 2005)

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Introduction of Mrs. G

When I met Mrs. G through the CCMS, she was teaching in a rural middle school in North Carolina. During her third year of the project, she transferred to a metropolitan high school approximately 30 miles away from the middle school. Since her new teaching assignment did not include algebra I, she had to leave the CCMS Project, but she introduced the TI-NavigatorTM to her new technology-deprived school. In an email conversation in June, 2008, Mrs. G told me that since graduating college in 1970, her professional career has consisted of teaching middle school and high school. From her early years of teaching, Mrs. G claims to have been a reflective and innovative practitioner. She and her colleague would stay after school and write some of their own materials. After implementing them, they would meet again and discuss their usefulness (Mrs. G, 2008).

From the time graphing calculators first came to Mrs. G's attention, she was enthusiastic about using them in her classroom. In an informal conversation, Mrs. G stated, "Once graphing calculators came into existence, I wanted to explore their use and experiment with how they could be used in the math classroom to improve student learning. I am always looking for workshops to help me learn more about technology and how students learn" (Mrs. G, 2008). A major focus of the CCMS professional development sessions was using the new technology, TI-Navigator™ to facilitate pedagogical techniques such as classroom discourse, levels of questioning and formative assessment.

As I made repeated visits to Mrs. G's classroom from the beginning of her participation in the project, I observed that she strove to implement the pedagogy via the new technology in her classroom. Her approach, her success, and her enthusiasm made me want to analyze her work at a much deeper level. Why was this professional development successful with Mrs. G? What aspects of her work could be attributed to the project? What could be learned from her classroom to further inform future professional development? In order to provide insight into these issues, my task was to study her classroom in depth. This process sought to align her use of the TI – Navigator™ to implement classroom discourse, levels of questioning and formative assessment with the professional development she received as a participant in the CCMS Project and to attempt to delineate the personal characteristics she brought to the project that allowed her to be successful.

Definition of Terms

Classroom discourse: This refers to the level at which students and teacher verbally communicate with one another (Nystrand, Wu, Gamoran, Zeiser, & Long, 2003). The lay term is often "discussion" but discourse is multidirectional and more specifically looks to teacher to student, student to teacher and student to student communication.

Levels of questioning: This refers to the type of question a teacher asks and the depth of response s/he requires from her students (Manouchehri & Lapp, 2003). Low level questions require only an answer, often only one word. High levels of questions require elaboration and/or justification.

Formative assessment: This refers to assessments embedded with instruction and is used in making immediate judgments about student learning and understanding during the course of the lesson, and making adjustments accordingly as the lesson unfolds (Black & Wiliam, 1998).

Social Construction of knowledge

"Human motivation is a complex phenomenon, so it follows that mastery orientation is dependent on many…factors, not necessarily explainable by a single theory," (Owens et al., 2005, p. 10). However, this dissertation is framed on social constructivist theory, whereby individuals construct their own knowledge, and that knowledge is constructed in a social environment(Cobb, 2007; National Research Council, 2000; van Oers, 1996; von Glasersfeld, 1993). Much emphasis has been placed on students learning in exploratory environments. Unfortunately, the same theory has often been neglected in teacher learning.

Discourse

Discourse is an intuitive tool for social construction. In many traditional classrooms, the teacher attempts to transfer her knowledge to her students by way of lecture and showing examples--teacher to student interaction. Lecture is not conducive to the social requirement of this learning theory. Learners must be allowed to discuss their findings amongst themselves and with the teacher. A climate in which learners are encouraged to share their reasoning in multi-directional discourse—student to student and student to teacher--allows for a rich and complex knowledge base as opposed to the perhaps thin, superficial, algorithmic learning that may come from lecture. This type of discourse “opens the floor to discussion and the negotiation of ideas and new understanding” (Nystrand et al., 2003, p.7).

Levels of questioning: an element of discourse in classroom

In order to generate the level of discourse that lends itself to rich learning, the teacher must be prepared with questions that spawn such interaction. A teacher may think that she is involving students in the lecture by including questions but, if she is asking low levels of questions with pre-scripted answers and accepting only correct answers, usually from the same few students who will guarantee to keep the class moving along quickly, she is doing little more than lecture. The type of questions being asked moderates the level of discourse in a classroom. For instance, in reference to solving the equation $x^2 = 9$, the teacher in a traditional classroom may ask, “What is the square root of 9?” and a few students will respond, and the teacher will move on. Consider the same equation in a room where a teacher aims to generate student discussion. The teacher may say, “Everyone think for a minute about as many ways to represent this equation as you can, and then see if your neighbors have anything different from you.” The latter teacher is addressing the same equation, but insisting on the students being responsible for their own learning as well as that of their classmates. In a sense, “teachers’ questions control students’ learning” (Manouchehri & Lapp, 2003, p. 563).

Formative assessment: students communicating concept gaps to teacher

Formative assessment involves continually reflecting on student learning and making adjustments as misconceptions are exposed. Classroom norms that allow for learners to openly discuss their thinking are likely to expose misconceptions so that they may be efficiently addressed, (Black & Wiliam, 1998; National Research Council, 2000). Classrooms that are built on a social constructivist paradigm naturally lend themselves to formative assessment where students are motivated to reflect upon and reorganize their thoughts to build their knowledge. A continual dance of relating ideas and receiving feedback from teacher and fellow learners naturally occurs. Classrooms that are built on a theory that knowledge is transferred from teacher to learner focus more on summative assessments whereby the teacher gathers completed work and evaluates it with a grade; then moves on with little opportunity for learners to rethink and revise.

Introduction of Mrs. G Classroom Observations

While making classroom observations for CCMS Project, one teacher, Mrs. G, stood out as intrinsically interesting to me. This teacher's classroom appeared to be one where the students and the teacher were enthusiastic about learning mathematics. This seasoned teacher seemed to be utilizing the technology and techniques from the project to promote an exciting and energetic learning environment where her students had a safe place to make inquiries and offer ideas. I noted that Mrs. G seemed to employ formative assessment, classroom discourse, and multiple levels of questioning. My initial judgment of Mrs. G's classroom practices came from being in her classroom for observations following the protocol for the CCMS Project, and is only a surface level of analysis. These initial observations lead me to believe that much could be learned for a richer deeper analysis. Therefore, I conducted a case study to gain deeper insight into factors that influence her teaching.

Research Questions

The research questions for the CCMS Project, found in Appendix A, address teacher changes that affect student achievement. From the project's set of research questions, I identified three constructs that I observed in Mrs. G's classroom that formed the core of an indepth case study. The research questions for my case study are: What effect did the professional development Mrs. G received in the CCMS Project have on her classroom practices in the areas of classroom discourse, levels of questioning and formative assessment? Secondarily, what aspects of her work could be attributed to the project? And, what could be learned from Mrs. G's classroom to further inform teacher preparation and professional development?

Why a Case Study?

Upon observation, Mrs. G's classroom appeared to have many of the components touted as desirable for student learning. Even for an outside observer, there was a feeling of excitement about being present in her class. Sharan Merriam (1998) states that "a case might be selected because it is intrinsically interesting; a researcher could study it to achieve as full an understanding of the phenomenon as possible" (Merriam, 1998, p. 28). There are many factors contributing to the phenomenon: the arrangements of desks, classroom procedures, student autonomy, classroom discourse, student-to-student interaction and types of questions and responses. I identified three constructs, classroom discourse, levels of questioning and formative assessment, to investigate while observing Mrs. G's classroom. Conducting a case study allowed me to investigate these constructs in depth and within the authentic context of the classroom.

These constructs were carefully and specifically addressed in the professional development sessions offered by CCMS Project.

A case study is a desirable method for this data because the whole culture of the classroom is under observation. Robert Yin recommends a case study for research when it is impossible to separate the phenomenon's variables from their context (Yin, 2003). Whereas an experiment seeks to control for all but one variable and focuses on how that variable influences many variables, a case study seeks to explore how many variables influence one case. A case study "illustrates the complexities of a situation – the fact that not one but many factors contributed to it" (Merriam, 1998, p. 30 citing Olson). Case studies are also "more contextual- our experiences are rooted in context, as is knowledge in case studies. This knowledge is distinguishable from the abstract, formal knowledge derived from other research designs" (Merriam, 1998, p. 31 citing Stake).

Mathematics programs have recently received a great deal of attention as American mathematics students continue to score below their counterparts from other countries in studies like the Third International Mathematics and Science Study, TIMSS (US Department of Education Institute of Educational Sciences). With so much effort being poured into teacher preparation programs and professional development seminars and workshops, it may be useful to examine classrooms that exemplify a desirable learning environment. Adding appropriate case studies to the database of "applied fields of study such as education… can bring about understanding that in turn can affect and perhaps even improve practice,…evaluate programs, and inform policy" (Merriam, 1998, p. 41). Conducting a case study of a teacher who is remains enthusiastic about making changes in her classroom practices to improve student learning will contribute to the literature on how to instill in pre-service teachers and practitioners the importance of life-long learning.

As most current theories of student learning have shifted from a behaviorist platform to that of cognitive psychology, much emphasis has been placed on how students learn. Recent research focuses on strategies to help students seek deeper understanding of mathematics, make sense of what they are learning and make connections to prior knowledge. Less attention has been given to strategies to engage teachers in similar learning experiences as they learn new ways of teaching (Putnam & Borko, 2000). "In order to realize the goal of enabling students to become autonomous learners, it is necessary that teachers of mathematics also become autonomous learners…and teachers who are self-sustaining, generative learners both sustain changes in their practice and continue learning after the end of a professional development project" (Warfield, Wood, & Lehman, 2005, p. 440).

Studying a seasoned teacher who continues to learn about desirable constructs in her classroom can add to the knowledge base of successful professional development. This study can inform pre-service and in-service programs to build programs that nurture a desire to continue learning.

CHAPTER 2

LITERATURE REVIEW

This chapter will review the literature related to successful professional development efforts that result in teacher change. The constructs for teacher change highlighted in the literature review are classroom discourse, levels of questioning, and formative assessment.

Teacher Change

The literature review suggests some useful avenues for improving continuing education for teachers that yield results. Numerous good ideas may be falling by the wayside or resulting in superficial changes; however, it seems that "teachers volunteer for professional development experiences that they believe hold the promise of enhancing their teaching. Such willingness greatly facilitates change" (Hyde, Ormiston, & Hyde, 1994, p. 51). How might the system harness this valuable resource of teachers who are willing to change? An underlying theme is that teachers must consider themselves learners (Taylor, 2002). "Schools will not be improved for children unless schools also become places for teachers to learn" (Sowder, 2007, p. 160). When the administration allows teachers to make decisions about their educational needs, they begin to establish places for teachers to learn. Professional development occurs when teachers are treated as professionals and are allowed to create their own "learning spaces" (Clement & Vandenberghe, 2000).

When this foundation has been established, teachers must have time to grow. In cases where professional development is viewed as a lifelong, self-actualization process rather than a summer event, substantive changes take place (Sowder, 2007). P. Mark Taylor uses an "inertia" model from physics to describe the conditions under which teachers consider themselves learners. Sir Isaac Newton's explanation of the inertia theory is "a body, from the inert nature of matter, is not without difficulty put out of its state of rest or motion" (Taylor, 2002, p. 3). Taylor's theory is that "teachers who view themselves as learners (in motion) are likely to evolve and grow in their teaching (stay in motion). Teachers who view themselves as having completed their fundamental learning upon their initial certification (at rest) tend to make only superficial changes in their teaching (stay at rest)" (Taylor, 2002, p. 3). Mathematics teachers habitually remain within the confines of their classrooms. Strategies for learning, such as seeking professional development opportunities by reaching outside their classrooms, across curriculum, grade bands, state and nation are more readily realized when pre-service teachers are in programs that support these new habits. Taylor suggests that pre-service teacher programs "immerse" prospective teachers in theory and practice and "instill" in them "professional habits necessary to keep mathematics teachers and their students actively engaged long after their initial certification" (Taylor, 2002, p. 4).

Clement and Vandenberghe (2000) refer to this type of learner as "progressive professionals" who automatically deem themselves accountable for work in their classrooms. They are eager to try innovative ideas and refine their practices throughout their tenure. These teachers seek out learning opportunities, creating these opportunities for themselves if necessary. There is a tension between autonomy and collegiality which must be reconciled to give teachers the license to grow professionally within their communities while maintaining their individuality. Schools must provide teachers with this professional “learning space.” (Clement & Vandenberghe, 2000). The powerful term “progressive professional” (Clement & Vandenberghe, 2000) adequately depicts the desired outcome of teachers who are continually searching for ways to improve their teaching - *reforming* versus *reformed*. Rather than being treated as isolated, discrete, professional development events, in order for substantial change to occur, one must treat growth as a daily process. Change is a life-time process, and so it takes a life time, not a summer or after-school event.

The literature has much to report on some positive changes that address the deficiencies in collegiality in American schools. The National Research Council emphasizes “the importance of shared experiences and discourse around texts and data about student learning and a necessity for shared decisions” (National Research Council, 2000, p. 198). Taylor addresses the importance of the “habit of seeking the help of colleagues, as well as sharing what they have learned” (Taylor, 2002, p. 3) and that this outreach goes beyond the boundaries of classrooms, schools, and districts. “Through reflecting on lived experiences and having dialogue with others, teachers begin to reconstruct what it means to be a learner and teacher of mathematics” (Castle & Aichele, 1994, p. 4).

Judith Sowder (2007) includes a review of effectively empowering teachers from Hargreaves. In addition to sharing learned experiences, collegiality also bears the fruit of teachers who are risk takers and have a stronger sense of efficacy and in cases where teachers believe that they are profiting professionally by their collegial participation, the communities are more likely to remain intact (Sowder, 2007). These traits are requirements for such pioneers in the “next frontier” (Stigler & Heibert, 1999, p. 2) as they emerge from their isolated comfort zones and embark on a collective transformation.

The Italians have a successful model call *Nuclei di ricerca didattica* (Nuclei of didactic research) in which university researchers and teachers of all levels join their individual competencies and experiences thereby “collectively construct(ing) a more adequate answer to the needs of society” (Malara & Zan, 2002, p. 569). The success of this project is attributed greatly to the fact that the practitioners “receive neither money nor help from their own institutions [but are motivated primarily] by idealistic and cultural reasons” (Malara & Zan, 2002, p. 569). The researchers suggest readings, problems and hypotheses to expose the practitioners to theories. When they have some common framework and language, the teachers partner with the researchers in light of their practice. The conflict here is not between practitioner and researcher, but that the traditional teacher is becoming a researcher, and this is a “temporary and fruitful” conflict whose solution “leads to a growth in awareness” (Malara & Zan, 2002, p. 572). This model is similar to the Classroom Connectivity in Promoting Mathematics and Science Achievement (CCMS) model for professional development which is outlined later.

Another successful trend that is becoming more popular is “job-embedded, practice-based and collegial forms of professional development…that rely on learning from collegial reflection and dialogue as much as for outside expertise” (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003, p. xv). Van Oers describes a Vygotskyian action psychological approach that utilizes the “characteristic aspect of human action… that humans can reflect on the execution of their actions and subsequently can improve or even radically change their performance” (van Oers, 1996, p. 99). Action research, whereby teachers are the researchers, data collectors, and analyzers, is a valued form of the job-embedded professional development. Malara and Zan turn to the teacher-researcher Iaderosa to highlight meaningful research for practitioners. “Meeting the world of research puts a teacher in a condition of tension towards a study that, beyond every deadline, never ends, because one sees that knowledge must be built day by day, it is not a ready-made stock to be conveyed: this is very important, and it belongs to the teaching profession as soon as it becomes an attitude to be conveyed with one’s experience, to other teachers too” (Malara & Zan, 2002, p. 572). The National Research Council touts action research for its constructivist approach in a social setting thereby reinforcing the importance of sustained teacher learning and opportunities for teachers to teach each other (National Research Council, 2000).

Adult Learners

Some of the literature suggests that adults learn best in an environment that is conducive to social construction of knowledge (Jacobs, 1998; Nyikos & Hashimoto, 1997). Nyikos & Hashimoto use a cognitive apprenticeship (CA) model to describe Vyzotsky’s zone of proximal development (ZPD) as a productive learning environment for adults. In CA, there is someone who is more knowledgeable about a situation or subject and the apprentice who desires to learn about the subject. The important aspect of this relationship is that “power sharing and mutual understanding are required for the ZPD to function” (Nyikos & Hashimoto, 1997, p. 508). In an environment where one person is the holder of knowledge and continually dominates the learning and the other person simply follows along, construction of knowledge is greatly hindered. Critical thinking occurs when both parties are held responsible for asserting and justifying new ideas and opinions. “For learning to be mutually beneficial, *especially among adults*, all parties must engage in critical thinking" (Nyikos & Hashimoto, 1997, p. 508, emphasis added).

Richard Jacobs (1998) borrows Donald Schon's designer studio model for his study in instructional leadership (Jacobs referencing Schon *Educating the Reflective Practioner*). In the design studio model, the master designer and new learner work collaboratively to synthesize complex ideas. The master must be willing to make new knowledge accessible to the learner, and the learner must be willing to have new learning experiences. This takes place with reciprocal reflection, and the master refrains from telling. In a classroom environment, the notion that the professor has knowledge and experience to share with her students gained throughout years of research and practice is relevant. However, when teaching adults, communication evolves into transactional behaviors where the professor and students are reciprocally involved in constructing knowledge from available resources. The professor refrains from an autocratic, manipulative environment but rather "engages students in giving voice to their learning" (Jacobs, 1998, p. 3).

In both of these models, issue is made that the expert assists the learner while not imposing his beliefs and attitudes. The learner is given allowances to construct meaning from her own experiences and prior knowledge. As classroom teachers are learning about their own teaching and their own students, they must be given the freedom, resources and responsibility to make decisions about their own professional growth and for their classrooms.

Principles of Professional Development

The following "ten important principles of professional development" (Clarke, 1994, p. 38) are incorporated into the project design. According to Clarke, in order to be meaningful and fruitful, professional development shall:

- address issues of concern and interest largely (but not exclusively) identified by the teachers themselves, and involves a degree of choice for participants;
- involve groups of teachers rather than individuals from a number of schools, and enlists the support of the school and district administration, students, parents, and the broader school community;
- recognize and address the many impediments to teachers' growth at the individual, school, and district level. The impediments include inadequate theory of implementation; the lack of sustained central office support, funding and follow-up; lack of joint planning time with other teachers, and the lack of work together in classrooms that leads to a feeling of professional isolation; the lack of commitment to, and ownership of proposed changes; the "practicality ethic" held by teachers (i.e., if a proposed innovation is not seen as practical in terms of classroom implantation, it will be rejected); the lack of link between theory and the realities of the classroom; an emphasis on correcting deficits rather than encouraging professional growth; the lack of incorporation of knowledge about teaching and learning into the content and style of the staff development program;

- using teachers as participants in classroom activities or students in real situations, model desired classroom approaches during in-service sessions to project a clearer vision of the proposed changes;
- solicit teachers' conscious commitment to participate actively in the professional development sessions and to undertake required readings and classroom tasks, appropriately adapted for their own classrooms;
- recognize that changes in teachers' beliefs about teaching and learning are derived largely from classroom practice; as a result, such changes will follow the opportunity to validate, through observing positive student learning, information supplied by professional development programs;
- allow time and opportunities for planning, reflection, and feedback in order to report successes and failures to the group, to share "the wisdom of practice," and to discuss problems and solutions regarding individual students and new teaching approaches;
- enable participating teachers to gain a substantial degree of ownership by their involvement in decision making and by being regarded as true partners in the change process;
- recognize that change is a gradual, difficult, and often painful process, and afford opportunities for ongoing support from peers and critical friends; and
- encourage participants to set further goals for their professional growth.

Discourse Directionality

In the spirit of learner-centered classrooms, there has been a movement to get students more actively involved. In attempts to engage students, sometimes teachers will put out nominal attempts at class discussion. To a well intentioned teacher, it may feel as though students are meaningfully engaged because they are speaking, but careful distinction must be made between discussion and discourse. Class discussions are often teacher led and superficial. The teacher may bait students with loaded questions, fishing for her preconceived answer. S/he calls on several students until the desired response is offered. This feigned script is still a dichotomous, teacher-centered activity. A much richer environment moves the level of discussion to discourse.

Nystrand et al., 2003, makes distinction between monologic and dialogic discourse. The former is a one-sided quest for a ready-made truth, impacted by power relations. This form of discourse is recognized by the teacher prompting a student or students with a question, usually that of lower order where a brief, pre-scripted answer is sought, followed by a student's response and finally the teacher's evaluation of that response. Using an initiation-response-evaluation (IRE) technique, the teacher calls upon students until someone finally delivers the teacher-valued answer. There is very little difference in this questioning technique and a teacher lecture. In this situation, students have little hope of becoming conversants in a naturalist inquiry. Conversely, dialogic discourse "opens the floor to discussion and the negotiation of ideas and new understanding" (Nystrand et al., 2003, p.7). Student utterances are treated as "thinking devices" as the teacher responds to previous student answers and remarks (Nystrand et al., 2003, p. 7).

Thus, the "*structure* discourse is one that is multidirectional and responsive. The *content* of the dialogues is dynamic, connected, and unscripted" (Manouchehri & St.John, 2006,p. 545, emphasis in original). Participants in a rich discourse are willing to listen openly to other's ideas and consider adjusting their own beliefs about the topic "thus, a major product of discourse is the transformation of its participants" (Manouchehri & St.John, 2006, p. 545). In a traditional classroom, the interaction between teacher and students is typically unidirectional with the purpose of "transferring information and… dissemination of facts" but discourse is used in learning communities to "assist both the teacher and students in learning more about the subject" (Manouchehri & St.John, 2006, p. 546). There is a sincere effort by all parties to develop new knowledge and shared understandings.

Discourse fosters authentic mathematical inquiry and veers away from the notion that the teacher and the textbooks are the authority on knowledge. The teacher's role in this sort of learning environment is not one of delivering knowledge, but more of managing discourse. By "requiring students to verbalize what others have said and what they might have meant by it, teachers can make it easier for reluctant students to contribute to group discussions" (Manouchehri & St.John, 2006, p. 51). The teacher also has a responsibility to set the pace of discussion, ensuring everyone gets time for thinking. Albeit a more secondary role than in the traditional classroom, the teacher's authority is still important to students as "learners' perception of what the teacher values can determine the extent to which they participate in and benefit from discussions" (Manouchehri & St.John, 2006, p. 551).

The following is an example given from a science class for language-minority, grade-school students. The Cheche Konnen approach, whose Haitian origin means search for knowledge, "stresses how discourse is a primary means for the search for knowledge and scientific sense-making" (National Research Council, 2000, p. 182).

> The Cheche Konnen approach to teaching began by creating "communities of scientific practice" in language-minority classrooms in a few Boston and Cambridge, MA public schools. "Curriculum" emerges in these classrooms from the students' questions and beliefs and is shaped in ongoing interactions that include both the teacher and students. Students explore their own questions….[and construct] scientific understandings through an iterative process of theory building, criticism, and refinement based on their own questions, hypotheses, and data analysis activities. (National Research Council, 2000, p. 182)

Building this community of practice is supported by social constructivist theory. It is an environment where no one individual, not even (or especially not) the teacher is responsible for the knowledge. The teacher is there as a guide, and the students direct the course of learning, taking responsibility for each other's thinking and doing. They challenge and synthesize one another's thoughts and examine their own, reorganizing their epistemological beliefs as necessary. From September to June, the students move to a path of scientific thinking – not just superficially armed with correct answers. In fact, there are still student misconceptions revealed by interviews with the project researchers. However, with students' willingness and knowledge of verbalizing his thinking with classmates and teacher, those misconceptions become uncovered and are in position to be amended (National Research Council, 2000).

Levels of Questioning

Often, time is of essence in the mathematics class, and the teacher feels pressure to "cover" so many concepts that students will be accountable for on high stakes exams. In these situations, teachers may think that they are being more productive by bombarding students with large volumes of questions in a small amount of time. In order to do so, they ask low levels of questions to ensure correct answers. They also may direct their questions toward students who are most likely to answer correctly in order to move on quickly. In this case, there is not time for thinking after questions are posed, there is no time allotted for discussion, and the needs of struggling students are neglected (Black & Wiliam, 1998).

The questioning techniques a teacher employs are important tools because questions inform the direction of the discourse, the students' reflection on their learning and formative assessment. In a sense, "teachers' questions control students' learning" (Manouchehri & Lapp, 2003, p. 563). Lower levels of questioning that require known, one-word answers may inform the teacher who can produce correct answers, but questions that ask students to explain and justify their thinking result in desired levels of classroom discourse. Manouchehri and Lapp (2003) refer to these question levels as "closed form" and "open form" respectively. An example of closed form is, "does everyone understand the method of elimination?" (Manouchehri & Lapp, 2003, p. 564) which informs the teacher which students believe they have an understanding of the current topic. However, it is a conversation killer since the responses do not lend themselves to further discourse. An example of open form is, "when is using the elimination method in solving systems of linear equations more advantageous than using other methods?" (Manouchehri & Lapp, 2003, p. 564). This question allows for student discussion and a deeper revelation of their knowledge of the concepts. The teacher may then take the information from the classroom discourse and reorganize the day's lesson if necessary, to help students build concepts.

Formative Assessment

As supported by constructivist theories of learning, students learn when their thought processes and beliefs are challenged, and they reorganize their thinking as a result of reflection on their own thinking. Formative assessments allow for teachers and students to evaluate understanding and construction of knowledge during the course of instruction so as to identify and correct misconceptions during the learning process. Traditional assessments negatively target the lower-achieving students. Students who do not typically receive the "gold star" treatment on their marked paper begin to believe that it is a reflection on their ability and adopt a deficit theory of learning mathematics (Black & Wiliam, 1998). They assume that they are incapable of learning more mathematics "thus they avoid investing effort in learning that can only bring disappointment" (Black & Wiliam, 1998, p. 4). While formative assessment has been found to improve the achievement of all students, it is with these lower-achieving students that formative assessment is most beneficial. Their misconceptions are exposed and remedied as they occur, rather than evaluated pejoratively in a summative assessment after it is 'too late' to show what they have learned. So, while raising the achievement level for all students, the achievement gap between the lower- and higher-achieving students is narrowed.

Before students can benefit from formative assessment, teachers' attitudes and beliefs must be conducive to such an environment. “If the teacher assumes that knowledge is to be transmitted and learned, that understanding will develop later, and that clarity of exposition accompanied by rewards for patient reception are the essentials of good teaching, then formative assessment is hardly necessary” (Black & Wiliam, 1998 p. 6). Rather, for formative assessment to be utilized effectively, students must have opportunities to express their understandings with one another embedded in the context of every lesson, and so “instruction and formative assessment are indivisible” (Black & Wiliam, 1998 , p. 5). “Dialogue between pupils and a teacher should be *thoughtful, reflective, focused to evoke and explore understanding, and conducted so that all pupils have an opportunity to think and express their ideas”*(Black & Wiliam, 1998, p. 6).

CHAPTER 3

METHODOLOGY

Overview and Research Questions

Many reform efforts are in place to encourage teacher change from a traditional, behaviorist approach to a social constructivist approach to learning. This study describes the instructional practices of a teacher who appears to be exhibiting characteristics of a social constructivist during her participation in the Classroom Connectivity in Promoting Mathematics and Science Achievement (CCMS) based at The Ohio State University (OSU). The purpose of this study is to describe the instructional practices of a teacher whose classroom exhibits the following three constructs considered instrumental in enhancing student learning: discourse directionality, level of questioning, and formative assessment. The research questions for my case study are: What effect did the professional development Mrs. G received in the CCMS Project have on her classroom practices in the areas of classroom discourse, levels of questioning and formative assessment? Secondarily, what aspects of her work could be attributed to the project? And, what could be learned from Mrs. G's classroom to further inform teacher preparation and professional development? Further, the study will examine these constructs in light of the professional development she received in context of the CCMS Project.

The first part of this chapter will give a brief description of the CCMS Project followed by the professional development of the CCMS Project to detail the learning environment of the participating teacher. This chapter further describes the case study:

participant selection, professional development opportunities, data collection, and analysis. Bias and validity issues will also be reported and addressed.

Brief description of the CCMS Project

The Classroom Connectivity in Promoting Mathematics and Science Achievement (CCMS) based at The Ohio State University (OSU) is a project to study the affect of wireless communication, in a classroom, on student achievement. The participants are self-selected and must be familiar with using a graphing calculator. The qualitative portion of the study includes teacher interviews, student focus groups, student and teacher attitudes and beliefs surveys and videotaped classroom observations. Videotapes are transcribed and coded to determine the implementation of the pedagogy emphasized in the professional development sessions of the project.

There are multiple parts to the intervention for the CCMS Project. Technology for the project includes TI- Navigator ™, a classroom set of graphing calculators and a laptop computer for every classroom during the years of participation in the study. The TI-Navigator ™ is most effectively used with a digital projector so that student responses may be posted for the whole group to view, which aids students in monitoring their own progress. The intervention also includes an intensive professional development component.

Professional development in the CCMS Project

Required professional development for participants includes a week-long training session at The Ohio State University led by Teachers Teaching with Technology (T^3) instructors and follow-up professional development at T^3 International Conferences for the years they are involved in the study. Additional professional development support is provided by on-line training and help as needed, a web-based forum for teachers to share ideas, concerns and questions, as well as experiential learning and experimenting with the software and equipment in teachers' classrooms.

The following paragraphs summarize the literature by using Doug Clark's "ten important principles of professional development" (Clarke, 1994). Each principle is followed by a description of how the CCMS Project employs these principles. According to Clark, successful professional development shall:

1. Address issues of concern and interest largely (but not exclusively) identified by the teachers themselves, and involves a degree of choice for participants.
   - CCMS participants were self-selected. They learned about the opportunity to be involved in the project from information about upcoming project at a national conference or by an email message. The assumption of this study is that teachers would not be applying to CCMS if they were not interested in using TI-Navigator™ in their classrooms.
2. Involve groups of teachers rather than individuals from a number of schools, and enlists the support of the school and district administration, students, parents, and the broader school community.
   - Although the principal investigators of the CCMS Project did not rule out individual participants, the preference was that teachers be taken in teams from school buildings or at least districts. However, this was a preference and not a requirement for participation. The teacher in this case study was the only algebra teacher in her cohort from her school. A science teacher from her school joined the study in a later cohort.

3. Recognize and address the many impediments to teachers' growth at the individual, school, and district level. The impediments include inadequate theory of implementation; the lack of sustained central office support, funding and follow-up; lack of joint planning time with other teachers, and the lack of work together in classrooms that leads to a feeling of professional isolation; the lack of commitment to, and ownership of proposed changes; the "practicality ethic" held by teachers (i.e., if a proposed innovation is not seen as practical in terms of classroom implantation, it will be rejected); the lack of link between theory and the realities of the classroom; an emphasis on correcting deficits rather than encouraging professional growth; the lack of incorporation of knowledge about teaching and learning into the content and style of the staff development program.

- Lack of sustained support and funding: Administrators agreed to let the teachers participate for a three-year period, including agreement to buy the equipment at a reduced price and allow teachers leave time for T^3 conference.
- Lack of joint planning time with other teachers, and the lack of work together in classrooms – all leading to a feeling of professional isolation: With joint planning time a physical impossibility, a list serve was created for teachers to regularly share ideas of implementing TI-Navigator™ use in classrooms. There was also the hope that those who came in pairs would have local support of each other.
- The lack of commitment to and ownership of proposed changes: As aforementioned, it is assumed that since the participants are self-selected, they are committed to the project and have ownership in it. Although, from the original

127 participants, some of the initial enthusiasm for the project waned, as was expected.

- The "practicality ethic" held by teachers (i.e., if a proposed innovation is not seen as practical in terms of classroom implantation, it will be rejected): The TI-Navigator™ is efficient by nature, so there was little argument that project was practical. Having T^3 instructors who are regular classroom teachers, present the TI-Navigator™ at the initial training session in the context of its usefulness in classrooms purported its practicality.
- The lack of link between theory and the realities of the classroom: In conjunction with the "practicality ethic," having presenters at the initial training session who are active classroom teachers realized that link. Juxtapose this scenario against other professional development training sessions whereby the presenters are selling their wares.
- An emphasis on correcting deficits rather than encouraging professional growth: At no time were participants reminded that the test scores in the US pale in comparison to other countries with the implication that teachers are not doing their jobs. The project was genuinely pitched as a desire to know what effect the TI-Navigator™ has on student achievement. It is a question, not an accusation, and no guarantees.
- The lack of incorporation of knowledge about teaching and learning into the content and style of the staff development program: During initial training and throughout the project, reminders of pedagogy and continued discussion and opportunities for questions were made available by the list serve and semi-annual

telephone interviews. Issues such as formative assessment, classroom discourse and self-regulated learning were emphasized.

4. Using teachers as participants in classroom activities or students in real situations, model desired classroom approaches during in-service sessions to project a clearer vision of the proposed changes.
   - The initial meeting used T^3 instructors, who are regular classroom teachers, to model their uses of the TI-Navigator™ in their own classrooms. Subsequent professional development sessions used video tapes of participants using the TI-Navigator™ in ways that support the pedagogy discussed in principle number 3.
5. Solicit teachers' conscious commitment to participate actively in the professional development sessions and to undertake required readings and classroom tasks, appropriately adapted for their own classrooms.
   - Naturally, commitment is a characteristic of the teacher and not the project's professional development, but the literature suggests that "in many instances, teachers who were lukewarm about or wary of their innovation demonstrated, after receiving appropriate peer and external assistance, a strong commitment that had not been present at the program's commencement" (Clarke, NCTM1994). So, to ensure optimum levels of competence, the project offered intense initial training with cohort model, efficient technical support, user-friendly list serve and web sites, and follow-up professional development at training sessions provided for participants at T^3 conferences.
6. Recognize that changes in teachers' beliefs about teaching and learning are derived largely from classroom practice; as a result, such changes will follow the opportunity

to validate, through observing positive student learning, information supplied by professional development programs.

- While there is still much to be learned about the *process* of change, the school of thought supported here is that change in beliefs is not linear. The assumption of the CCMS Project is that participants have some belief at the beginning of the project that the TI-Navigator™ has potential to make positive changes in their classrooms. Then, when the teachers experience the increased student discourse, enthusiasm and willingness to learn that results in increased achievement, their commitment to modifying their classrooms is cemented, and their beliefs are reforming.

7. Allow time and opportunities for planning, reflection, and feed-back in order to report successes and failures to the group, to share "the wisdom of practice," and to discuss problems and solutions regarding individual students and new teaching approaches.
    - As part of the week-long intensive training session, teachers worked in pairs to prepare lessons that might be useful in their classrooms, and had the opportunity to share them with the group. With physical distance an issue, participants were encouraged to share information of this nature on the list serve. Teachers have a place to ask for help or ideas as well as share success stories. They had opportunity during semi-annual telephone interviews to share successes and challenges with a member of the research team.
8. Enables participating teachers to gain a substantial degree of ownership by their involvement in decision making and by being regarded as true partners in the change process.

- Participants are regarded as more than just mere data providers in the CCMS Project. Their ideas and feedback are a crucial element of the research. It is widely accepted that the participants' feedback is used in decision making because the teachers are the ones who are actually using the TI-Navigator^{TM} system, and not the professors. Without the participants' faithful involvement the project would be fruitless. The PI's make every effort to make most of the classrooms observations themselves. A participant from a small, rural school that was a four-hour drive from the airport was impressed that the principal investigator of the project made the effort to take a trip to her school.

9. Recognize that change is a gradual, difficult, and often painful process, and afford opportunities for ongoing support from peers and critical friends.

    - The CCMS PIs take heed that sustained support is essential to ensuring the fidelity of the participants. The cohort model is utilized by the CCMS group in hopes that during the training week, the bonds formed among participants will serve as ongoing support throughout the project. The participants depend upon each other for logistical and pedagogical support via email and the list serve. Semi-annual telephone interviews, user-friendly technical support and intensive sessions at the T^3 conference are all key factors of the sustained support provided by the researchers.

10. Encourages participants to set further goals for their professional growth.

    - Participants are invited and encouraged to share what they are learning with their building mates and others. Some have become the building 'experts' with the TI-Navigator^{TM} system and have even written grants to get more sets of the

TI-Navigator™ on their campuses. As part of the ongoing professional development, CCMS offers sustained support by encouraging and providing for trips to the T^3 conference every year. It is expected that at these conferences, participants will attend other sessions to glean insight on other recent technological advances.

The Case Study

Participant selection for the case study

The subject of this case study, Mrs. G, is a teacher who is a participant in the CCMS Project. I was assigned by the principal investigators to observe her classroom because it was within convenient driving distance of my community. As I collected data from her classroom for the project over a three-year period, I noted that this seasoned teacher was enthusiastic about the project, about learning something new, and about teaching and student learning. Decidedly, this teacher made a good candidate for a case study. I wanted an in-depth look into her classroom practices.

The case study as method

A case study is a desirable method for this data because the whole culture of the classroom is under observation. Robert Yin recommends a case study for such a study when it is impossible to separate the phenomenon's variables from their context (Yin, 2003). Whereas an experiment seeks to control for all but one variable and focus on how that variable influences many, a case study seeks to explore how many variables influence one case. A case study "illustrates the complexities of a situation – the fact that not one but many factors contributed to it" (Merriam, 1998, p. 30 citing Olson). Case studies are also "more contextual- our experiences are rooted in context, as is knowledge in case studies. This knowledge is distinguishable from the abstract, formal knowledge derived from other research designs" (Merriam, 1998, p. 31 citing Stake). The intent is to evaluate the events of a teacher's classroom in the context of the larger CCMS Project. Guba and Lincoln (1981) "conclude that case study is the best reporting form for evaluations…because it provides thick description, is grounded, is holistic and lifelike, simplifies data to be considered by the reader, illuminates meanings, and can communicate tacit knowledge" (as cited by Merriam, 1998, p. 39). Kenny and Grotelueschen point out that a case study is a tailor-made approach when it is "important to be responsive, to convey a holistic and dynamically rich account of an educational program" (as cited by Merriam, 1998, p. 39). Conducting a case study will allow me to investigate the constructs of classroom discourse, levels of questioning and formative assessment in depth and within the context of the classroom. For example, rather than simply counting the number of times a student speaks during class as a quantitative report may do, I will be able to describe the context of the utterances: How much wait time was allowed? How were the desks arranged? Were the utterances prompted by the teacher? If so, by what level of question or comment? A significant piece of this study is adding to the data base of professional development opportunities that work. By conducting a thick description, I was not able to not only count the constructs such as evidence of dialogistic discourse in a classroom, but I was also able to discuss it in context of the professional development that Mrs. G experienced about generating discourse from the sessions at OSU and T^3 conferences. I watched the videotapes of these professional development sessions and the videotapes of Mrs. G's classroom observations. I aligned the constructs of classroom discourse, levels of questioning and formative assessment with her professional development opportunities.

Data Analysis

The literature review indicates that teacher beliefs and attitudes must change before substantive changes can take place in the classroom (Thompson, 1992). I used the teacher beliefs and attitudes survey from the CCMS Project to identify Mrs. G's beliefs about teaching mathematics.

The video-taped observations of Mrs. G's lessons are transcribed and coded by a codebook developed by a qualitative research team from the CCMS Project. Yin suggests testing procedures used to code the data for reliability to minimize the errors and biases in a study (Yin, 2003).

Development of the codebook

Originally three people, including the author, from the CCMS Project, which included a principal investigator, met for a four-day training session on the coding. The terms were redefined many times as the team scrutinized the videotapes and coded transcripts. This meeting resumed two months later and added a fourth member to the coding team. We met at the University of Florida campus where two of the team members were located. During this meeting, we viewed tapes, coded transcripts and discussed techniques to focus the definitions of the current codebook. To achieve reliability, the goal was to have an 80% consistency rating. This was not accomplished during the face-to-face meeting, so we held telephone conferences for the next three months to test our inter-rater reliability.

Using the codebook and NVivo software, I will code the classroom discourse using line-by-line analysis for levels of questioning, directionality of discourse, and evidence of formative assessment. NVivo is a qualitative tool that keeps record of the amounts of transcripts that are coded as low order questions, for instance, as a numerical count as well as percentage of the transcript. I will use the percentages from NVivo to record teacher change in these areas from her initial project participation from fall 2005 through fall 2007.

I am tempted to make inferences about formative assessment when observing the class. I may interpret something as formative assessment through my own lens, but the teacher may actually have this particular lesson plan in mind initially. To be certain of evidence of formative assessment, I used transcribed telephone interviews and post observation interviews to code evidences of formative assessment. It is difficult at times to properly code evidences of formative assessment in the classroom transcripts. In order to be coded as formative assessment, it must be clear that the teacher has changed something about her lesson plan for the day to accommodate the learning needs of the students. Because teachers do not typically write very detailed lesson plans, it must be clearly evident from the transcript that the teacher is using formative assessment because she makes the statement that she is making changes during the lesson or that she habitually makes changes during lessons to accommodate student learning. Even after taking these measures to identify formative assessment, it may not be clear. When the question remains whether the lesson plan was adjusted to accommodate student learning, I viewed the lesson in question with Mrs. G and asked her to recall whether the event involved a change in lesson plan.

The telephone interviews and post-observation interviews document teacher change by asking *before* and *after* questions. The interviewer asks questions regarding change in classroom climate, pedagogy, classroom interactions such as, "Are there any major differences between the atmosphere in your connected classroom in this academic year compared with classes in other years [before you started using TI-Navigator™]?"

Student focus groups occur out of class during the days of an observation. Evidence of teacher change also comes from analyzing student focus group transcripts. In the student focus groups, students are asked to elaborate on survey questions from the class. Students are asked to make statements about life in a TI-Navigator™ classroom, and often the researcher can capture emerging themes about teacher change from the student comments.

The literature also suggests that evidence of teacher change is that teachers are willing to share their knowledge in a teaching environment. As a teacher's sense of self as a mathematics teacher evolves, she is "more likely to want to share this passion with… colleagues, to feel a commitment toward empowering others to teach principled mathematics" (Sowder, 2007, p. 168). The CCMS teachers using TI-Navigator™ met for a professional development day with the investigators preceding each T^3 International Conference. At the 2006 T^3conference, teachers around a table shared a lesson plan they had brought for that purpose. Each table group selected one lesson to share with the summary session of all table groups. Mrs. G was nominated by her table group to share. Her presentation to the plenary session was videotaped. That tape is available for analysis as evidence of Mrs. G's development to that point in the project.

Evidence of permanent teacher change is that the teacher continues in her new practices after she has left the project (Warfield et al., 2005). Mrs. G changed schools and subsequently left the CCMS Project. In brief telephone conversations soon after her move in spring of 2008, Mrs. G told me that her new school was technologically deprived and she was working with the administration to bring the TI-Navigator™ to the school. She was to train her fellow staff members on its use. I made a two-day classroom observation that parallels that of the CCMS Project at her new school, to determine if indeed she continued to implement the pedagogy that was emphasized in the CCMS Project. The observation followed the same protocol and qualitative analysis as the observations of her classroom as a project participant. I audiotaped and transcribed a two-day visit of Mrs. G's new classroom. I coded the transcripts using the same codebook that was established as a guide for the larger project's observations, paying attention to classroom discourse, levels of questioning and formative assessment. I again aligned the observation with the professional development that she received as a participant in the CCMS Project. I also conducted a post-observation interview asking Mrs. G if the professional development she received in the project made an impact on her teaching practices.

Validity issues

From the beginning of the study, I enjoyed visiting Mrs. G's classroom. She treated her students well, and it was an energetic and pleasant place to be. I had made note that when observing classrooms, if the teacher was likeable and kind to me and her students, I wanted her to be a reforming teacher. I am reporting this bias and took the following measures to conduct a valid case study.

While much of the literature grapples with handling the elusive validity issue of qualitative research, Merriam brings to light this wisdom from Walcott:

> Walcott argues the "absurdity of validity." Instead of validity, what he seeks "is something else, a quality that points more to identifying critical

> elements and wringing plausible interpretations from them, something one can pursue without becoming obsessed with finding the right or ultimate answer, the correct version, the Truth." For Walcott the "something else" is understanding (Merriam, 1998, p. 201, quoting Walcott).

Merriam delineates some commonly accepted strategies to enhance internal validity (Merriam, 1998, pp. 204-205):

1. Triangulation of data--using multiple sources to confirm emergent findings.
   - I have videotaped and transcribed classroom observations, post-observation interviews, spring and fall telephone interviews, student focus group interviews, descriptions of classroom layout, videotape of Mrs. G's presentation to the other teachers at T^3 conference, teacher attitudes and beliefs survey, and student attitudes and beliefs surveys. I have audiotapes and transcripts of Mrs. G in her new environment. I used the same coding scheme from the CCMS Project observations to determine if she continued to implement the pedagogy emphasized in the professional development sessions of the project. In a post observation interview, I asked Mrs. G to consider whether or not the professional development sessions in the CCMS Project had an impact on her teaching practices.
2. Member checks – taking data and tentative interpretations back to the people from whom they were derived and asking them if the results are plausible.
   - I did not discuss my dissertation topic of professional growth with Mrs. G while I was actively involved in collecting data from her classroom because I did not want to prompt her to seek more professional development or prompt her to answer interview questions according to what she thought I was hoping to hear.

- I did not discuss coding the transcripts with Mrs. G because the research team that is coding data is coding the transcripts based on what is said and not on what the teacher meant. Since my coding is based on inter-rater reliability training, I coded with consistency of the other raters and not the teacher's biased thinking of what she thought she said or meant to say.
- According to Merriam (1998), many writers suggest member checking throughout the study. I chose not to do that for validity's sake, but I shared the results with Mrs. G at the end of the study and asked her if she thought the results were plausible. She read the dissertation and agreed that she perceived the results and conclusions to be accurate.

3. Long-term observation at the research site – gathering data over long periods of time to increase the validity of the findings.
    - I observed 19 class periods over the period from fall 2005 to fall 2007 and I have videotapes and of the observations.
4. Peer examination – asking colleagues to comment on the findings as they emerge.
    - I am working with a qualitative research team that is coding all of the transcripts for the larger study, so I am in regular contact with colleagues regarding coding transcripts. We code the transcripts in various pair wise combinations to check our codes. To ensure consistency, various members of the qualitative research team checked my coding for my dissertation.
5. Participatory or collaborative modes of research - involving participants in all phases of research from conceptualizing the study to writing up the findings.

- In this case, it would bias the data if I involved the participant in all phases. For instance, suppose I said to the participant that I was focusing my study on teacher change in conjunction with teacher autonomy, and then in a telephone interview, I asked how the atmosphere of her classroom is different since using the TI-Navigator™. She may have emphasized changes or inadvertently enhanced or even fabricated evidence.

6. Researcher's biases – clarifying the researcher's assumptions, worldview, and theoretical orientation at the outset of the study.
   - Before beginning my literature review, I wrote a lengthy journal including personal and professional factors that have influenced my self-actualization. I pared that journal down to my thoughts and feelings regarding the environments in which I was able to develop as a teacher and those that had hindered my growth.

CHAPTER 4

DATA ANALYSIS

While collecting data for the Classroom Connectivity in Promoting Mathematics and Science Achievement (CCMS), I became acquainted with Mrs. G, an eager participant. As I made many visits to her classroom over a three-year period, her enthusiasm for implementing the TI-Navigator™ in her instructional practices never waned. I was intrigued by the energy with which this teacher pursued student learning. Mrs. G, a seasoned teacher, showed no signs of burn-out or disillusionment common after many years in the profession. Rather than preparing to retire, she was gaining momentum. In my final interview with her, she passionately told me about becoming involved in the project. Her words revealed her initial desire to be a part of this nationwide project and confirmed my suspicions that she had an internal need to use all available resources to reach her students, and she considered it her job to do so.

> I saw [TI-Navigator™] at a technology conference… There was another summer workshop that was offered by the last county I was teaching in, and it was called Algebra I for the Learning Disabled. It was a full week workshop, all day at [a local university]. It addressed different strategies for teaching algebra 1 to those kids who really have struggled. One of the instructors had the Navigator and spoke about it a lot. It just got me researching it. And once I researched it, I called Texas Instruments, and they sent out a representative to discuss Navigator—to show Navigator. She wanted to show it to the teachers, principals, superintendents, and I said, “No, I want to see it in the hands of the kids because I am not going to make a decision unless I see it in the hands of the kids.” So she spent an entire day…She came in with Navigator, and they were all engaged. It was like, I could not believe it. Wow. This is going to work! And I picked my lowest level of kid to do this because a lot of things work with the upper level kids, but they don’t work with the lower level. Once I saw it was really going to work and then I saw how much it was going to cost, basically the principal said, “You are only going to get this if you can find a grant.” And I started looking for grants…the rest is history. I was nervous that I wasn’t going to get accepted because they wanted algebra

> one teachers from high school in the beginning. They weren't taking any middle school, and I was middle school.

Mrs. G was emotional as she recalled the fear of being turned away from the project. Her fervor indicated her resolution to implement the new technology in her classroom. Mrs. G's vested interest in the CCMS Project raises the following research questions: What effect did the professional development Mrs. G received in the CCMS Project have on her classroom practices in the areas of classroom discourse, levels of questioning and formative assessment? What aspects of her work could be attributed to the project? What could be learned from her classroom to further inform teacher preparation and professional development? This chapter is an analysis of the data collected during the three-year period that Mrs. G participated in the project.

The facilitators of the professional development sessions offered by the CCMS Project made the statement on a number of occasions that "there is no silver bullet" meaning that the TI-Navigator ™ was not a cure for all classroom ills. In fact, the new technology is not useful by itself. The TI-Navigator™ can only do its job in a classroom where the teacher creates an environment conducive for identifying and rectifying misconceptions. The TI-Navigator™ allowed for student work to become an object of discourse and thereby a teaching tool. In this dissertation, I am focusing on three pedagogical constructs which were highlighted in the professional development sessions: *classroom discourse*, *levels of questioning* and *formative assessment*. The subsequent sections will follow this sequence: (1) sessions from the professional development that explicitly address the construct; (2) comments Mrs. G has made regarding the construct; and (3) evidence from her classroom observations that she is employing the constructs as she professes. The final section is a report of a teacher beliefs and attitudes survey that Mrs. G completed as a participant in the CCMS Project.

Classroom Discourse

An important aspect of the social construction of knowledge is interaction among learners. Naturally, in order to share their ideas about mathematics with each other, students are forced to justify assumptions and thoughtfully form their schemes in a cohesive manner. Since many students are accustomed to a teacher-focused classroom where students are passive learners, a constructivist teacher must be intentional about creating situations for students to freely talk about mathematics.

Using the TI-Navigator™ to synchronously collect and post student responses, allows everyone's thinking, whether anonymous or not, to be viewed by the large group. This presents the opportunity for discussion about students' correct and incorrect responses. Recognizing that not everyone would recognize a technological tool as a means of promoting discussion, the principal investigators and the T^3 instructors made specific references in the professional development sessions to the advantages of discourse.

CCMS Professional Development on Discourse

Throughout this chapter, I will use the following notation to indicate the source of the quotation: Dr. Stephen Pape, CCMS Principal Investigator (SP); Dr. Louis Abrahamson, CCMS Principal Investigator (LA), student (S), students (Ss), participant (P), interviewer (I), teacher (T), Mrs. G (Mrs. G).

The following is an excerpt from the initial professional development session. It is Dr. Stephen Pape's introductory comments connecting the importance of discourse to his involvement with the project, followed by some responses of several participants, including Mrs. G:

> SP: And the immediate feedback, and the discussions that you can have after it, are what got me into this grant. I am so excited about that data that you can get. You saw it already. What kind of conversation might you have with this? Now this is some math problem, but you have these data now. What kind of conversations would you have about that?
>
> SP: [Referring to a pilot project] the students gave themselves away. "Oh, that was me!" Depending upon your classroom norms and how comfortable the students are with you, they are going to give themselves up. "That was me, and I did this." But they articulated it. They talked about the strategy that got them to the wrong answer. It's helpful to see what the person did wrong so they understand.
>
> P:(Mrs. G) What I find a lot is there's only one right answer in math. And when they see this, they're going to know that there's more than one right way to present your answer.
>
> P: This will take us to a point where we're doing a lot less teaching. The goal obviously is to get kids talking and get us quiet, and once they start to catch on, they start to tell each other, “Oh, no. This isn't what we need to do try this...” and then all of a sudden, the discussion is by the students rather than one person.
>
> P: Student-to-student discourse. They're not afraid to speak up to a neighbor rather than the teacher.
>
> P: Further discussion of what other people did that was perfectly legit, but maybe completely different than your thoughts.
>
> SP: That's where orchestrating discussion comes in. If you're looking at homework and you see where they made mistakes. But if they put in wrong answers and you ask about the strategies that are being... how did they arrive at the wrong answers, then all of these folks are getting their wrong answers corrected. I apologize for stepping on toes, but we give feedback to individuals, and this allows us to give feedback to the group.

This illustrates the project’s modeling of the pedagogical importance of discourse. Pape not only talks about the importance of student interaction, but models it by asking the participants what kinds of conversations they might have. He then allows time for them to imagine what might come about in the classroom. The participants respond according to their understanding of the goals of a connected classroom in light of discourse.

The participants gathered at the International T^3 conference in Denver following their initial experiences with the TI-Navigator™ to share their experiences and for further discussion on the targeted constructs. The following conversation in a large group session discussion is one in which a participant makes some insightful contributions regarding the teacher's role in generating discourse:

> P: I'm hearing all these things about it does this, it does that. But I feel like it becomes another tool. It doesn't create all this. Maybe it helps you get to the point where you interact in a different way. But that doesn't mean that you can't have those things without it. And so I think we need to consciously be developing the kind of discourse that we want and with and without the TI. If it helps you to develop that, [but] I don't think it's made it easier for me. It's given me another avenue.
>
> SP: Right. We still have to create the climate. We still have to ask the questions, and we have to push the students to explore their responses. So we are still the person that is doing it. I don't believe anything in education is a silver bullet at all.
>
> P: There can still be some fairly shallow discussions with the Navigator. We have to make sure to take it beyond that. It can be used as an electronic worksheet or to grade multiple choice tests where that might need it for certain reasons, it doesn't guarantee a deeper conceptual discussion.
>
> …….
>
> P: Students are more responsible for their learning ?
>
> SP: I hope so. Yes. If we look at the idea of uptake of incorrect responses, it's really important that we have the students analyze the strategies that they are using to get the correct as well as the incorrect responses. Because that will support them in doing that at the obligation phase when they are doing the problems on their own. I really want to push you to the point to think about how are you looking at those incorrect responses as well as those correct responses? How are you having them analyze the

situation in order to figure out which strategy they should use? So when you do substitution method, for solving systems and you do the graphing method, so in which case is it appropriate? In which equation should I solve for one variable and then plug in the other one? How can I make that decision? Try to ask them those questions so they get at the idea of, "I have a choice here, and I need to make a decision, and I need to have a reason why I do things."

…..

SP: I have a solution. I think it's really important—it's called collective argumentation. I think we as a group are supporting the learning of each other. If we make that a norm, then maybe they would try to explain rather than give the response. So, Chris is going to add a little bit to this discussion, and Lynnlee is going to add a little bit to this discussion, and we keep pulling from the students rather than telling them. Perhaps that will support them in helping each other, because they will learn how to do that. I don't know that they know how to do that.

Again, the above statements illustrate the participants understanding of the usefulness of the connected classroom in light of classroom discourse. However, this time the participants have had the new technology for more than one semester. They are sharing their new knowledge of the TI-Navigator™ as practicing in a connected classroom, and not simply imagining what it might be like to have this new technology.

Mrs. G's Comments about Her Perception of Discourse in Her Classroom

In this chapter I report comments addressing classroom discourse that Mrs. G made in telephone interviews for the duration of her participation in the project: After having the TI-Navigator™ for the first year, I conducted a telephone interview with Mrs. G in fall of 2006 when she revealed that using screen capture, which posts everyone's calculator screen activity, was producing discussion. Her comment was, "So, when I did a screen capture, the graphs were so different: some linear and some curves. This generated so much more discussion on what makes the curve versus what makes the straight line." She was already a believer that student discussion of their understanding of mathematics generates learning. In these passages she talked about the TI-Navigator's™ contributions to classroom discourse.

> *Spring 2006:*
> Mrs. G: But it has assisted and validated the way I have been teaching. I feel it's a battle to get them to think on their own, and Navigator has fostered more discussion from quieter kids that normally you wouldn't get.
>
> *Fall 2006:*
> Mrs. G: I probably would only interact otherwise with those who are more vocal. It fosters more discussion about the "hows" of doing a certain problem. It allows you to interact with the quiet ones as well.
>
> I: Can you think of a particular situation?
>
> Mrs. G: Their voice is heard because they are able to have input into the lesson or the question, or whatever it is that you are doing. Before it was the ones who were very vocal and always responding that almost directed the... made the decision on which way the class is going to go. You've got the whole class picture. It's very different. The kids who always have the answers are obviously the kids who are always right, and you get the feeling that everyone gets it. When you ask a question and get the answer from only one or two people, it is very different from when you ask a question and everyone answers. The adage "squeaky wheel gets the most grease" doesn't work in a Navigator classroom.
>
> *Spring 2007:*
> Mrs. G: Students are more involved. Students are helping each other more. They're talking more about math. [It's] like the example I gave you before about the kid who was multiplying. Some kids kind of know what to do but don't have the math language and vocabulary to be explaining it so when you say, "How'd you get that?" they say "I don't know." This has facilitated more discussion.
>
> Mrs. G: …when you think about what students are used to in a classroom for years, as far as the teaching style, and then they come into a TI-Navigator™ classroom where they're expected to talk and to support their answers, as opposed to just, "What's your answer?" I don't know. For some of them it's uncomfortable and foreign, and they're used to teachers telling them how to do the problem and what to do… I think they're slow to take responsibility for their own work. That's not what they've been used to.

Fall 2007:

> Mrs. G: It's just that the second… you can be talking and kids you think most of them are listening to you and most of them are getting it, and the second you say, "No, no, don't answer me. I'm going to screen capture your calculators, and I'm going to see what you're doing…." The increased participation is probably—you have almost everybody at that point where you didn't before because they're motivated to be part of the whole environment, to see their work on the screen, to know how they did in comparison to everybody else. I hear, "Oh, now I know what I did wrong. Oh, now I understand that." It's more them helping and teaching each other.

These excerpts were selected as illustrations of Mrs. G's perception of the discourse generated in her classroom over the course of the project. Overall, her understanding is that classroom discourse is important to student understanding and the teacher's knowledge of student understanding. She acknowledges this point in a number of different ways as noted in the above comments such as: giving quiet learners a voice, hearing from all learners-not just the "right" ones, knowing what a student thinks about the "hows" of the problem, taking responsibility of their work and pressing students to vocalize their understanding.

Levels of Questioning

Embedded in the conversations supporting classroom discourse was the notion that the teacher fosters this desirable environment with the type of questions she asks. Levels of questioning, while embedded within discourse was treated as an additional construct in the professional development aspect of the project. It was suggested that the questioning techniques employed by the teacher inform the classroom climate for discourse. As the participant mentioned in the previous section, the TI-Navigator™ teacher has a specific role in creating an environment where the classroom norms are that of talking about mathematics, shamelessly exposing and analyzing student errors, and students' creative ideas are not suppressed but readily welcomed. Many students come to a TI-Navigator™ classroom from traditional environments of teacher telling, where the teacher is the mathematical authority and the holder of knowledge. Students are to listen and learn. So, the TI-Navigator™ teacher must stimulate her students with questions to prompt them to participate. Sometimes the questions are simply to involve students in the task at hand, but some questions are of a high cognitive level, inviting the students to engage their thinking on an analytical plane.

CCMS Professional Development on Levels of Questioning

The following passages are excerpts from the professional development sessions that specifically address the teacher's role in instigating discourse with the kinds of questions she asks:

> T^3 instructor: With Quick Poll and later with class analysis, it changed my way of questioning. Instead of saying, "Well, how did you get that?" That's too accusational. Even though I wasn't meaning that. I now change it to say, "How would someone get that?" It alleviates that feeling of, "I'm the only one that was wrong, and how am I supposed to explain it? I have no idea." But it also gives the students who frequently or most often get things right, it gives them an opportunity to look at perhaps someone who has not done it the same way they did, and they can help talk through what would be the possibility of getting that. Is it just one step away from being finished? Or whatever.

At a T^3 conference, the CCMS participants were asked to share at their tables how their intentional questioning lends itself to students talking about mathematics.

> SP: So, rather than the teacher explaining, we hear a lot more from the students.
>
> P: Right.
>
> SP: We hear a lot more about the student solutions. How are you asking them?
> How are you helping them to be able to do that?

Mrs. G's Comments about Her Perception of Levels of Questioning in Her Classroom

In a face-to-face interview with Mrs. G after she left the project, I asked her what role questioning has in her classroom. She responded that she uses questioning to gain understanding of her students' knowledge of mathematics and that she varies the levels of questions she asks to challenge students who quickly grasp new concepts and to include students who struggle.

> I: What is the role of questioning in your classroom?
>
> Mrs. G: I usually question to assess what they already know on a topic before we start a new topic or to connect something we have learned to something we are going to be learning. I question for understanding. I question for keeping students on task.
>
> I: What do you do with your question for understanding? What do you do with that?
>
> Mrs. G: I'm not sure I understand this question.
>
> I: Well, when you say you question for understanding, so you're in class, and you ask students questions to see if they're understanding what you're currently working on, or…
>
> Mrs. G: Right, and to basically assess whether or not they are understanding it, and then, I mean it directs what I'm going to do next. Whether I keep going, or back up to re-explain or back way up. You know, re-teach something they need before we go on.
>
> I: Okay, and you've addressed this a little bit already, but I need to ask again, what do you do to employ different levels of questioning during your instruction?
>
> Mrs. G: Yes. And I guess sometimes (inaudible) because I'm with the weaker students. If it's just a knowledge question, I might direct it at a certain student to make them feel like they can contribute, um, and then I really work for higher level thinking skills. Some of those, if I just question, I let students answer; I don't call. Sometimes I specifically call on a student, and other times I'll just have them raise their hands.
>
> I: So you will specifically ask a question that you know that they can answer so that they will sort of have a place of value in the classroom.

Mrs. G: The other day—I have a boy that never should have placed in honors geometry—we can't figure out why he's here. I expect his parents really wanted him here, and he's failing miserably. I mean he just about failed algebra, and the algebra teacher recommended him for tech math, but he's in honors geometry. And we were doing a question; I guess it was in their quiz. It was a square, and I gave them apothem—and I asked them to find the area of it, and it was, as you looked at it—and this is the thing about them. I mean sometimes apothem means you use one half AP, and if it's a square, then you could have just doubled it, found the side of the square, then you're done. And [student] had done this, but most of the class hadn't. I mean most of the class had got this wrong, so when I put it up I said, "[Student], can you please explain this, you're one of the few people who got this right." And he went, "I did?" It was really kind of funny the way he did it.

I: I also mentioned this already that you have different levels of questions in the review game, and I think you've already addressed that, that they were all open to any of the students.

Mrs. G: [Nodded yes]

I: Okay. Well, and also I think you might have mentioned this too. Do you have any other examples of multiple levels of questioning in your classroom?

Mrs. G: I mean I gave you the homework. Do you mean verbal questions from me?

I: Any of it.

Mrs. G: You know, homework—when I give them different assignments.

I: So what about verbal questions? Do you have different levels of those in your…

Mrs. G: Yeah. And that's what I was answering to first. I mean, like when I'm explaining something, I'm going through a problem as we start it, and you know geometry is pretty multi-stepped, or you know, proofs. We start; it might be something that anybody could answer, and then as the proof gets a little bit more difficult, then those students that have the higher level thinking skills.

The above comments illustrate Mrs. G's commitment to questioning in her classroom. She uses questioning for various reasons, namely to involve students, and to expose their conceptual understanding. She sometimes uses low level questions to gain student involvement from those who maybe struggling, so they can be part of the community, and sometimes high order thinking questions to push students to pursue a deeper understanding.

Examples of Questioning Used to Instigate Discourse

In my many visits to Mrs. G's classroom over her three-year tenure in the CCMS Project followed by a post-project visit at her new school, Mrs. G's classroom was lively with student-to-student interaction, small group and large group discussion, verbal analysis of student work, and collective argumentation. It was always a high energy, interactive space, conditioned for learning. It would be impractical to list every episode of student interaction and discourse in this chapter. A summary of such findings will be discussed later in the chapter. However, I have selected a number of examples of classroom transcriptions that demonstrate Mrs. G's use of questioning to instigate students talking about mathematics and the norms of her classroom that welcome students' contributions.

The following excerpt from Mrs. G's first year in the project is a lively interaction between teacher and students. The posed warm-up question was one in which the students claimed there was missing information. Mrs. G engaged her class in an authentic discussion regarding whether the missing information was necessary to answer the question. Several students revealed their thinking; however, none of them attempted an algebraic solution. Mrs. G finally took a student's guess-and-check method and used it as a tool to model algebraic thinking.

Mrs. G: So Chris, what did you say about that first problem?

S: I did 3R times 4, minus 1 and 3 ____ 3R ___.

Mrs. G: And you got 25? Okay. Did you check it?

S: _____

Mrs. G: It says she gave four points for each right answer and took off one point for each wrong answer. Oh, my goodness, I think there's something missing from this.

Ss: ___ the answer.

Mrs. G: Yeah. How did I miss that?

S: We don't know how many problems.

Mrs. G: Huh. Can you do it without knowing what the problems are?

Ss: (talk over each other) 100 divided by ___?

Mrs. G: 100 what?

S: 100 percent

Mrs. G: You'd have to know how many points there are total. Right? And you don't know that because you don't know how many problems there are. Let's change this. There were 25 questions. Sorry, guys, how did I miss that? So, do you think your answer is right now, Chris?

S: No.

Mrs. G: Why?

S: Each question is worth 4 points, and you divide it by 4.

Mrs. G: Say that again?

S: To make 100 you get ___ so 100 divided by 4, because each problem is worth 4 points. There's 25 questions; _____.

Mrs. G: You are right. So you didn't need to know that there were 25 questions because you figured it out. All right. So Chris, what do you say now? You said she got what?

S: 25 right.

Mrs. G: 25 right. If she got 25 right and they're each 4 points. she would have got 100.

S: Yeah.

Mrs. G: And she didn't get 100. She got a 75. Does anybody have a different answer?

S: 18.75.

Mrs. G: You got what?

S: 18.75.

Mrs. G: 18.75… I can't hear. The question is, "How many did she get right?"

S: Yeah, because if you put 75 over 100 and there's a total of 25 _____

Mrs. G: So if she got 18 and ¾ right and she was getting 4 points for each one right, and then that means how many did she get wrong?

S: ____

Mrs. G: 6 and ¼ and she lost one point for each of that. Does 18 ¾ times 4 plus 6 ¼ times -1 equal 75? That's not so… What? I'll give you partial credit for things. So what was your answer?

S: I didn't find one.

Mrs. G: You didn't find one?

S: Well, I was wrong.

Mrs. G: It looks like you're almost there. Adam.

S: I got 20.

Mrs. G: You got 20 problems; and how did you do that?

S: ____

Mrs. G: Plus -1 or -1 for each one wrong, and how many did she get wrong?

S: 5.

Mrs. G: 5. Does that work? 20 times 4 is 80, plus a -5 is 75. How did you approach that problem? You know that's ____.

S: It's just an evaluation ____.

Mrs. G: Okay, and if you did guess and check, what am I going to tell you?

S: You need to write an equation.

Mrs. G: That writing an equation might be easier. So take me through your steps of what you did to get this guess and check. Step 1, Matthew, what was your first step?

S: _____

Mrs. G: What do you think your first step was if you're going to guess and check?

S: Guess what the number is.

Mrs. G: You guess the number. Okay, I'm guessing a number. What did you do after you guessed that number?

S: I guessed the number – I guessed one, and then I did ____

Mrs. G: So you did what? Chose that number from… How'd you get 5?
S: I guessed the number.

Mrs. G: You had 25 questions, and you guessed the number, and you took that number and subtracted it from 25. So, this was your number right, and this is your number wrong. Everybody following that?

S: Yeah.

Mrs. G: So then what did you do?

S: 20 times 4.

Mrs. G: 4 times 20, right? I'm just putting a variable in for what you're doing with a number, and then what?

S: Subtracted the number 1.

Mrs. G: 1, from whatever that answer was, and I don't have it because I'm putting a variable in. And what were you trying to get? What were you hoping your answer was going to be?

S: 75.

Mrs. G: Do you follow what I did? I just took every step he did, and I just substituted a variable for when he picked the number. So let's solve this equation. 4*x*…

Ss: plus -5____

Mrs. G: Um hum.

Ss: -5*x*+ plus__. Add ___ Wasn't it suppose to be negative *x*? And you divide each side by 5.

Mrs. G: So if *x* is 20 like he guessed, then 20-5 is 5 and…

S: It's 20.

Mrs. G: 25-5 is 20. Thank you. And 80-5 is 75. Okay.

The previous selection is evidence that Mrs. G engaged her students in authentic communication by probing with multi-level questions. The given problem seemed to be missing information, so the discussion turned from, "How does one find this answer?" to "Do we have to know how many questions were on the quiz to solve this problem?" Mrs. G is initially uncertain herself, but rather than dismissing it as a mistake in the textbook, she takes it on as a teachable moment, unconcerned that she was baffled along with her students. The above example of classroom discourse illustrates one of many cases where the students in Mrs. G's room are eager to share their questions and knowledge. It is an example of Nystrand's (2003) "negotiation of ideas and new understanding" (p. 7) which allows for rich and complex knowledge base as opposed to thin, superficial, algorithmic learning that comes from lecture.

The next excerpt from spring of her first year in the CCMS Project is an example of the teacher expressing her concern after a homework checking episode that the students have quite a few misunderstandings. Mrs. G simply provides an opportunity for the students to verbalize their issues, and they are quickly forthcoming with their needs.

> Mrs. G: Yes. Guys, I don't have a good feeling about last night's homework. And I need for you to talk to me about it. One at a time. Yes.
>
> S: What I did was I thought this meant slope intercept so I didn't do _____.
>
> Mrs. G: Chris?
>
> S: I did the things on the _____
>
> S: Most of them, I got the negative signs mixed up.
>
> Mrs. G: Are you using a calculator at home?
>
> S: Yes. If there's a negative ten and a negative 5, sometimes I forget there's a negative there.
>
> Mrs. G: Gary? Looking at this I feel like I have to re-teach it. But what I'm hearing is, no you don't, I understand it.
>
> Ss: I understand it. I understand it.
>
> Mrs. G: Wait a minute. Hands up.
>
> S: I forgot how to add and subtract the decimals. They messed me up.
>
> Mrs. G: All right. Were you trying to add fractions by hand at home, or were you trying to add them on the calculator?
>
> S: Calculator.
>
> Mrs. G: You need a common denominator, right? You remember that? Anybody else? Did you get them all right? Ming, talk to me about…
>
> S: ____
>
> Mrs. G: But talk to me about your understanding of this.
>
> S: It's hard.

Mrs. G: What makes it hard?

S: _____

Mrs. G: What?

S: When I was asking him ____ he'd say _____.

Mrs. G: He never had any fractions. You're right. Even if you don't reduce them, they're right. Anybody over here? So yes, do we need to go over this anymore? Yes? Raise your hands yes.

Ss: Yeah. Yes, because I got half of them or less. Yes. We need to review it and keep going over it.

Mrs. G: Yes, Chelsea.

S: I got like half of them right and half of them wrong.

Mrs. G: Let's follow Chelsea with one problem.

S: Why me?

S: Because you're asking for help.

Traditionally, a teacher ascertains student struggles silently from written work. In the above example, Mrs. G pleads with her students to openly communicate their needs to her so that they may be addressed in general forum, and everyone may reap the benefits. In the above example of using classroom discourse for the purpose of formative assessment, students orally reveal the troubles they had with slope including difficulty with negative numbers, fractions and calculator usage. This gives the teacher an opportunity to address specific student needs, rather than simply assuming that students do not understand the concept of slope.

This next example of classroom discourse, also from spring of her first year, demonstrates the value Mrs. G puts on her students' thinking, and their awareness of that, thereby assertively sharing their ideas with their teacher and fellow students. The students are graphing a system of equations to determine the best deal for a band to rent time in a recording studio. Since they are dealing with hundreds of dollars, Mrs. G suggests that no one would want to graph it by hand, but a student suggests adjusting the scale. A lively discussion ensues.

> Mrs. G: Pretty close. So, for an equation like this, who would want to graph it on graph paper?
>
> S: Nobody.
>
> Mrs. G: Nobody, you're right. So this would be a good one to graph on your calculator. You got the equation down, because I'm going to erase it. Have you got it written?
>
> S: Mrs. G, you can always do a scale.
>
> S: You could go by 25.
>
> Mrs. G: You could go by 25s?
>
> S: I like that idea, let's do it.
>
> S: Ms. G, you don't remember anything I said.
>
> Mrs. G: Okay, let's go by 25s: 25, 50, 75, 100. 25, 50, 75… We're going to run into trouble. Yeah, I think you're right.
>
> S: I say go by 5 and 10s.
>
> Mrs. G: So the Y intercept on the first one is here at 100. The slope is 50, which means 50 over… Oh, yeah.
>
> S: It's going to be about that big.
>
> S: I say go by 5s.
>
> Mrs. G: Let's go back to the calculator.
>
> S: 25s.

Mrs. G: Yeah, but you're going to go up 50, which isn't bad, but I'll be going over 100.

Ss: You haven't changed the *x* axis. You can make it 10, and then 5, and then 5, and then 7.5.

Mrs. G: Do you think so?

S: Yes, I do. And for the *Y*s, move the decimal.

Mrs. G: What did you say?

S: I said you could simplify it to make it 10 plus 5*x* equals.

Mrs. G: So, what are you doing?

S: Dividing by 10.

Mrs. G: He's dividing. Watch this, this is so… This is so cool.

S: He's just too smart.

S: He's not smart enough.

Mrs. G: We have… Follow his thinking. Is this going to work though, PJ?

S: Whenever you get your answer…

S: Multiply it by 10.

S: Multiply it by 10. I bet it will work.

Mrs. G: We need to have it—I was thinking, "Gee, that might be good," until I went to do this and divide both sides by 10 and got 10 plus 5*x* equals 1/10*y*. But the thing is, we want it in *y* equal form.

S: What I'm saying is just do it like regular but just ___ your calculator. 10 plus 5*x* ___, and then *y* equals that, and then *y* equals 7.5*x*, and when you get your final answer times it by 10.

S: That thing you kept back when you did the last thing.

Mrs. G: One at a time.

S: Like here's what I'm saying, I'm going to do it on the calculator. And I'm going to do the large scale on the calculator.

Mrs. G: Hold up. Don't do it before I give you the cord.

S: I can't use that cord.

Mrs. G: I've got the other ones, just take this. Tell me what the original one was.

Ss: 100 plus 50*x*. 50 plus 75*x*.

Mrs. G: Right now, can we watch this calculator? Just watch him for a second. I believe that zoom fit…

S: I don't need that.

Mrs. G: Guys, are you following what he just did? He hit zoom fit to fit the equation into the window.

S: 2,200. Do you want me to write that down somewhere?

Mrs. G: No. I want to talk about it for a second. What's the first equation you typed in?

S: The first equation I typed in was 100 plus the 50 *x*.

Mrs. G: So, the 100 dollar rental fee.

S: Want me to do that thing, where…? [changes mode on calculator split screen]

Mrs. G: What are you doing? Oh. Okay, oh, wow. So,put the calculator down, and look up here, please. Thank you, Chris. This first equation is 100 dollars an hour. No. 100 dollars plus 50 dollars an hour. Which one graphed first? Can you come up here and find which one is which? Up here. Find out which one is which.

S: Hit graph.

S: I'm working on it, slowly but surely. That's the 100 plus 50*x*.

Mrs. G: This one, okay? So, this is the 50 an hour plus 75. Now, what I want you to think about is this amount right here for this first equation. . .

S: 170.

Mrs. G: Is less money than this one. But where they cross, and it's hard to see. (Loudspeaker interruption) PJ, you said that the intersection was 2.

S: 2,200.

Mrs. G: So, that means for two hours you would pay the same no matter which room you rented, whether you spent the hundred dollars 50*x* plus 2 times 50 is 100. 100 plus 100 is 200. Or 75, which is (interruption – class applauds).

S: Everybody, please pay attention to Mrs. G. I tried.

Mrs. G: So, after 2 hours: 3, 4 ,5 hours, you're going to spend less money choosing this one than you are choosing this one.

S: At first you're spending more.

Mrs. G: But before the two hours, you going to spend less money choosing this one than you are this one. And the only time you're spending the same amount is at 2 hours. That's the reason, and we'll look again at this next week, that's the reason cell phone plans run differently. Certain video stores have a video membership, and then you rent movies for so much an hour, and you have to look at different options because there are times when one option is going to be better for you because it's going to be less money, and it just depends on your own circumstances. If you're only renting this… If you're in this place for 5 hours you're going to choose this one. If you only need it for an hour, you would choose this one. Does that make sense?

Again, the original problem becomes secondary as the students grapple with using an appropriate scale. Since this large-scale question is a good example to demonstrate appropriate use of technology, Mrs. G really desired a calculator graph. However, one of her students persisted with adjusting the scale so that one could reasonably graph it by hand. Ironically, the episode closes with the student checking his graph on the calculator, which was Mrs. G's original idea. Notice that even so, she did not hinder the student from chasing his idea with his classmates. Rather she encouraged him and called for everyone's attention while the student demonstrated his theory. One can conclude that students in Mrs. G's classroom may readily share their knowledge without fear of being "wrong" or chastised for chasing a new idea. This adds to the rich knowledge base of the community.

The following excerpt is one in which the teacher and student together discuss an appropriate method to survey students regarding the school lunch menu. Mrs. G has no preconceived ideas of acceptable responses or methodology, so students and teacher are able to have an authentic discussion where no one's contributions are valued over another's, thereby stifling students who may think their idea is not right. In the end, Mrs. G even admitted that she did not know a best strategy as the question asked for.

> S: I said no. . . because. . .
>
> Mrs. G: Okay, but the question is, "Would the data be representative of the entire school population?" and you're saying no?
>
> S: Because 10 students couldn't represent a population of close to 500 students because those students could have different opinions.
>
> Mrs. G: How many should they collect?
>
> S: You should collect at least enough to say you've asked like one fifth of the students.[inaudible]
>
> Mrs. G: Okay, so you're saying that they need to have *more* students to have it be representative. Ten students aren't enough.
>
> S: Yeah.
>
> S: I said no because it's just the 8th grade and not the whole school.
>
> Mrs. G: Well, it is a middle school. It does say middle school. Most middle schools have. . .?
>
> SS: 6th, 7th and 8th
>
> Mrs. G: Right. Most middle schools have 6th, 7th and 8th, or 7th and 8^{th,} or 7th, 8th and 9th, but at least 8th grade. But I think that's a very valid point that they should at least survey …
>
> S: More than half the students. Because you got a majority.

Mrs. G: Do you think you need to survey half of the people?

S: 51%

S: Somebody's going to say, "Yeah, I want a cheeseburger."

Mrs. G: I don't really know what the answer is to how many they should survey, but I think about the telephones calls we get usually at supper time, the annoying calls, and they're asking questions like, "Do you watch TV?" and "What shows do you watch?" I mean if they're—Suppose it's a cable company that's doing that, and they're trying to make decisions based on the area that they serve. Do you think that they have to survey half the people?

S: No

Mrs. G: I don't know what the answer to that is, but I'm guessing maybe "no." But I think his point is valid. Ten isn't very many.

S: Yeah.

Mrs. G: There's 10 on the survey and …

S: There's 10 from *each* homeroom.

Mrs. G: Pardon me?

S: Ten from each grade level.

Mrs. G: Oh, my goodness, Dexter, 10 students from *each* homeroom. So if a homeroom has 30 kids in it, and she surveys 10, is that not enough?

S: It should be.

Mrs. G: Thank you, Justin.

S: It still shouldn't be the first 10. The first ten in alphabetical order? Or the first 10 in lunchroom, or what?

Mrs. G: The first 10 that come in? The first 10 in alphabet?

S: It's still not…

Mrs. G: So, are you saying that maybe surveying the first 10 isn't random?

S: No, it's random, but what I'm saying is that you could have all 10 students say that they don't like cheeseburgers. In like 3 of the homerooms and you have like 5 homerooms, and 2 of the homerooms say that they do like cheeseburgers, and then majority rules. So, the majority rules in 3 homerooms because they don't like cheeseburgers, but majority rules in 2 homerooms' results in they do like cheeseburgers, but they could just keep cheeseburgers out because. . ..

Mrs. G: Tell me how you would do it. I want to know whether or not to add cheeseburgers to River Bend's menu daily. How would you survey that?

S: I would give them a ballot that has their favorite food on it, and I would have them vote as they come through the food line, like once every three.

Mrs. G: Okay, but the question isn't so much…the question is who are you selecting to survey?

S: Just randomly take half the homerooms.

Mrs. G: How would you randomly do it?

S: Like this. [random gestures with his fingers and eyes closed]

S: Yeah, just close your eyes and wave in the air.

Mrs. G: Okay. So, something that makes it random.

Ss: Yes.

S: Since they're just doing 8th grade, like the other grades might not like cheeseburgers, so just doing one grade might not show the results for the whole school.

Mrs. G: Yes, exactly. So we agree that this is not representative, and it is not representative because we are only doing the 8th grade, and maybe we need to do more random.

S: So, what is the strategy?

Mrs. G: I don't know what the strategy is.

S: It needs more information.

S: So, what's the strategy?

Mrs. G: I just said I don't know. You just need to think about it.

S: It's just thought basically.

This sample of discourse is more evidence of the quality, multi-directional nature of the discourse in her class. Mrs. G admittedly does not have a preconceived notion of the one correct way to sample students for their choice of lunch items. She had misread the question initially, so the students discussed the misread question briefly until someone brought the error to Mrs. G's attention. The class proceeded with discussion about the stated question. Interestingly, both questions yielded valuable discourse.

The final example is one in which the students have just been exposed to the concept of function using a "function machine." The teacher had examples of linear, quadratic and absolute value functions, and the students were testing various values to input into the machine. One student introduced the notion of acceptable values for the domain. His colleague raised the case of the vertical line. The teacher encouraged this discussion by letting the students verbalize their ideas without suppressing their enthusiasm.

Mrs. G: Everything again, you got it.

S: Do you always use *x* as everything?

Ss: No.

S: Maybe.

Mrs. G: Let me think about that. Maybe there are some times I can't use it.

S: I know one thing you can't.

Mrs. G: You think there's one that you can't?

S: Yes.

Mrs. G: What is it?

S: Whenever there's a line straight down with the *x* on it or a line like horizontal, [you] would use the *y*.

Mrs. G: He's asking about *X*s, not *Y*s.

S: It's like the *x*. If there's a line going straight down, then?

Mrs. G: Oh, I know what you're talking about! Oh my gosh! Do you know what he's talking about?

Ss: Yes. [inaudible]

Mrs. G: [inaudible] be that long?

S: Yes.

Mrs. G: Are you talking about when the line goes like this?

Ss: Yes.

S: Whoa.

S: You see the vertical going straight down.
Mrs. G: Oh, gosh. Is that good? Yes! Let's just say this is *y*, and this is *x*—you're right, because then all you're using for *X*s is…

S: That one number.

Mrs. G: That one number like $x = 5$ and you're not using anything else, right? Cool, Armando, very good.

This student had an idea about vertical lines, and Mrs. G credited him with good thinking. Mrs. G let the student own his mathematics. She was impressed with the student's ingenuity, rather than being annoyed that he had usurped her lesson topic for another day. Welcoming this kind of unscripted discourse encourages students to explore their ideas and share their reasoning with one another and the teacher. Student ideas are valued. Students are free to vocalize their original ideas, thereby adding to the knowledge base of the community themselves.

Quantitative Coding

Definition of Codes

Recognizing that isolated cases of student discourse do not paint a comprehensive picture of one's classroom, I conducted an extensive analysis of Mrs. G's classroom discourse. I used a codebook that was developed by the qualitative research team of the CCMS Project. I took complete transcripts of Mrs. G's classroom observations and imported them into NVivo software to count the occurrences of each construct. Each line of transcript was coded into one of the following nodes which I will briefly define. These definitions are summarized from the CCMS Algebra Classroom Observation Protocol Codebook (Pape, Owens et al., 2008). A complete codebook may be found in Appendix B.

> *Initiation, Response, Evaluation [IRE]*. Typically a 3-conversational turn sequence during which (a) the teacher initiates by asking a question, (b) a student responds, and (c) the teacher evaluates the student's response.
>
> *Uptake*. Uptake of correct and incorrect responses or student comment or question refers to the degree to which and ways in which the teacher "takes up" (i.e., explores, engages with, discusses, critiques, reasons about, provides rationale to support) responses and comments as objects of classroom discourse.
>
> *High order cognitive load question*. Elicit responses that may involve manipulation of information and ideas in ways that transform their meaning and implications - combining facts and ideas to synthesize, generalize, explain, hypothesize, or arrive at some conclusion or interpretation.
>
> *Low order cognitive load question*. Elicit recalling and stating information or known facts; carrying out a simple algorithm, math procedure, or problem solving steps to complete a task.
>
> *Scaffolding*. Scaffolding is social support for student achievement. Categories include activating prior knowledge, questioning and hints, supporting understanding, modeling, and summarizing.

Teacher press for elaboration, explanations, and justifications. Teacher presses students to elaborate their ideas or to make their reasoning explicit. Teacher follows students' answers with a request for deeper thinking.

Teacher press for involvement. General code related to identify teacher strategies for increasing involvement for all students.

Student-to-teacher mathematics comment. All mathematics statements from a student to the teacher including direct response to a teacher question.

Student-to-teacher mathematics question. The direction of the mathematics question is from a student to the teacher.

Student-to-student mathematics comment. All mathematics statements form a student to another student.

Student-to-student mathematics question. The direction of the mathematics question is from a student to another student.

Teacher-to-student mathematics comment. All mathematics statements from the teacher to a student or students including lecture about mathematics content.

Teacher-to-student mathematics question. The direction of the mathematics question is from the teacher to a student.

Teacher talk. All teacher talk that is not strictly math-content related.

Authentic question. Open-ended, no specified answer by question source.

Recitation question. Questions for which the pre-scripted answers are known by question source.

Eliciting multiple answers. Multiple answers may be implicitly or explicitly elicited by the teacher. Perhaps the teacher says, "Anyone else have a different response?" Or teacher lists all responses to a question.

Interpretation of Coding Outcomes

Five classroom observations of varying durations are summarized in Table 4.1. The first observation is year one, winter, which was a two-day observation of 90-minute class periods. The second observation was year one, spring, which was a five-day observation of 90-minute class periods. The third observation was year two, spring, which was a four-day observation of 60-minute classes. The fourth observation was year three, winter, which was a three-day observation of 60-minutes, and the fifth observation was made after the teacher left the project due to a school move. It was a two-day observation of 90-minute class periods; but on day two of the observation, the students participated in a game for the entire 90 minutes. The climate of continual talk among students in their teams made transcribing impossible for the purposes of quantifying the classroom discourse; however, the interactivity still provides meaningful data for the case study. For consistency, all quantifiable codes have been converted to a single day, 60-minute class period.

Table 4.1
Quantitative Summary of NVivo Coding Results

Code	Year 1 Winter 2006 2 days	Year 1 Spring 2006 5 days	Year 2 Spring 2007 4 days	Year 3 Winter 2007 3 days	Post project 1 day
IRE	14.4	4.67	21	29	18.76
Uptake	3 23%	1.88 14%	8.75 27.34%	7.67 16.24%	1.3 11.24%
High order	3 0.67 st	0.8 0.268 st	5 0.25 st	8.3 0.67 st	0.67 0
Low order	49.58 1 st	27.1 4.15 st	87.28 6.75 st	105.3 8.3 st	81.74 21 st
Scaffolding	5.7	2	10	10.3	2.68
Press elab	4.7	2	5	7	0
Press involve	10.72	2	4.5	10.67	0
S-T MC	72 5.77 wpc	40.5 7 wpc	116.25 5.5 wpc	160.3 4.8 wpc	142 4.8 wpc
S-T MQ	3.35	4.7	7.25	10	14.7
S-S MC	2.345 4.86 wpc	2.28 10.76 wpc	3 4.92 wpc	2.3 2.43 wpc	1 1 wpc
S-S MQ	0.34	0.27	0.5	0.67	0
T-S MC	29.14 23.6 wpc	26.4 23 wpc	31.83 18.4 wpc	40.42 17.17 wpc	73.7 22.7 wpc
T-S Q	50.59	20.52	82.75	102.3	67.67
Teacher talk	31.155 10 wpc	22.34 7.71 wpc	42.25 9.68 wpc	81 9.68 wpc	48.91 13.47 wpc
Authentic question	22 2.1 st	13.94 4.56 st	34.75 7.25 st	43.67 8.67 st	32.16 13.4 st
Recitation	42.21	13.69	56.5	71.3	50.92
Elicit mult ans	1	0.402	1.75	3.67	0

The above matrix summarizes the coded transcripts from Mrs. G's classroom observations. Since the duration of the class periods and observations vary, all counts have been converted to a single, 60-minute class period. With this display, one can readily see the number of times each of the constructs was observed in a class period. For the purposes of this case study, examples of transcripts are used to provide contextualized applications of each construct.

Initiation, response, evaluate (IRE). Typically IRE is an undesirable pattern in a classroom because it usually consists of low cognitive load questions and may be used as more of a lecture masked as student involvement. The evaluation component deems the teacher as the mathematical authority. So, an increase in IRE would be a disappointing result. The NVivo results show that Mrs. G increases from 14.4 episodes of IRE in year one, winter of 2006 and 4.67 episodes in year one, spring of 2006 (recall she suffered from laryngitis this time) to as many as 29 episodes of IRE in year three, winter 2007. However, Mrs. G employs non-traditional uses in her IRE pattern as shown in the following excerpts from the winter of year three.

These three excerpts show eliciting multiple answers.

Mrs. G: Does anybody have anything different than those two?

S: I do.

Mrs. G: Yes?

S: The steadiness of their pace?

Mrs. G: That their pace is steady. Good job.

…………..

Mrs. G: What are you using?

S: Speed and time.

Mrs. G: Good. Speed and time is good.

…………..

Mrs. G: Plus 2?

S: 3.

Mrs. G: Okay, somebody else give me a number? Tyler?

S: 10. It would be 12.

Mrs. G: Okay.

To future illustrate these concepts the following transcripts are provided. Whereas typical IRE is a teacher eliciting a short, predetermined response and stamping it with a verbal checkmark, the previous examples show Mrs. G's use of IRE is to invite student participation by eliciting multiple ideas. The following excerpt records Mrs. G pressing students to talk about their thinking about the new topic, concept of function. They are invited to brainstorm any ideas they have.

Mrs. G: All right. Look at your second set of points compared to the first, and I thought I had changed the color on that so it would actually—I thought I changed it. There we go. Look at your second set of points compared to the first. Talk to me about that. Just say something. Make a statement about it, but raise your hand to do it. Go ahead.

S: The green one's going through the origin.

Mrs. G: Oh, interesting. Yes. The green one went right through the origin, the other one did not. Good observation. Something else, Jacob?

S: They meet at (1, 1). They intersect.

Mrs. G: They intersect at (1, 1).

Ss: (1, 2)

Mrs. G: (1, 2) You're right, it is (1, 2). So let me just talk about that for one second. Look, that means that the first one which was $x + 1$, right? 1 + 1 is 2, and the second one is 2 times 1, and 2 times 1 is 2, and that's why because they both make that equation true. Something else? Anything else you want to say?

S: There's a positive trend.

Mrs. G: There's a positive trend, awesome. Anything else? Something else, Dorothy?

S: They're all real numbers?

Mrs. G: Yeah, they do. They're all real numbers, um hum.

S: It's a straight line.

Mrs. G: It is a straight line. Anything else? And that's important because pretty soon we might not see a straight line. Anything else? Shinika, you want to say something else?

S: I don't know. I mean I know [inaudible]

Mrs. G: [inaudible]? You can't see… We talked about… this one goes through the origin. This one actually goes through the point (0, 1), right? That they meet here, they're a straight line. Come on, something else. Jacob?

S: They all increase.

Mrs. G: They all increase, and I think somebody said positive.

S: Are you looking for y is…?

Mrs. G: I'm looking for observations about those two lines; anything you want to say about them. Shinika?

S: The green line is like closer in to the y.

Mrs. G: Yeah, it is. It's closer in to the y. How can you say the same thing? How else can we talk about that?

S: [inaudible] The y axis the angle is [inaudible]?

Mrs. G: Oh, the angle of the y axis and the line—I need another—the y axis and the line. I see what you're saying. That angle is smaller than that angle. Okay. So now number 3. I'm going to leave those two lines up and ask you to do number 3. Let me change the colors.

S: Send this?

Mrs. G: Not yet. So far everybody who sent it is doing it right.

S: Oh, number 1. I thought my numbers were number 1. [chuckle]

S: Then we probably have the same number.

Mrs. G: Oh-oh. I've got somebody that's off here. Scott. 3 times -4?

S: -12.

Mrs. G: -12 minus [inaudible] plus -2?

Ss: 14.

Mrs. G: Right, and watch. As soon as I put in -14 your point jumps down to that line. And who's this right here?

S: Me.

S: Carla.

Mrs. G: Carla. -5 times 2?

S: Oh, times 3.

Mrs. G: Oh, I'm sorry. -5 times 3.

S: -15.

Mrs. G: -15 times -2? Does anybody have the number -13 or positive 13?

S: I have -13, but I did it wrong, and it won't let me [inaudible].

Mrs. G: Oh, okay. Let me get so I can see all your numbers. Okay, all right, so talk to me about this one compared to the other two. Say something about that line. Carla, just say something. There's no right or wrong, I'm just asking you to make an observation.

S: It's a straight line.

S: It's a positive slope.

Mrs. G: It's another positive slope. Good.

S: It's a straight line.

Mrs. G: Yeah, it's a straight line.

S: Instead of like one more down, it goes like up.

Mrs. G: Oh, give it another name; more up.

S: Vertical.

S: Closeness

Mrs. G: Think about hills.

S: Slope?

S: Height?

Mrs. G: Think about skateboard ramps.

S: Vertical.

S: Height?

S: Steep?

Mrs. G: Steep, yeah.

SS: [clap]

Mrs. G: Is it steeper? Is the green line steeper than the yellow one and steeper than the orange one?

Ss: Yes.

Mrs. G: Yeah, so we're going to start to figure out what is it that makes it steep. What is it that's making that one steeper than the other.

Her evaluative remarks in the previous example are used to encourage her students to remain involved in the conversation. Her evaluation of student comments in this episode is followed by bids for another student to comment. She is using IRE to keep the conversation going where typically the evaluative comment by the teacher is the end of that very brief conversational turn. The next example of IRE is an invitation for students to analyze classmates' work.

Mrs. G: I'm wondering what people did here?

S: It's the highest place…

Mrs. G: Right.

Uptake. Mrs. G spends large percentages of time taking up student comments and questions as objects of classroom discourse. This exercise validates student contributions, therefore encourages student input. The first and third observations show nearly one fourth or more of the class time is spent on comments and questions instigated by students, thereby validating student contributions and allowing them to be holders of their own knowledge. This comes at a price. Mrs. G often runs out of class time before she finishes a lesson. In the post project interview discussed later in this chapter, she addresses this issue and makes no apologies for it. The lowest account and percentage of uptake is in Mrs. G's post project observation, but this may be due to one-day transcription and the fact that the lesson for that observation was new to students. Although they were actively learning and exploring geometric networks for themselves and imagining what they might look like as solid figures, they did not make many verbal contributions to the group discussion. Perhaps they needed time to think about new concepts before having innovative ideas and questions to share with the group.

Types of question. The recitation questions were all posed by the teacher, but the authentic, higher cognitive load and lower cognitive load questions were occasionally posed by student. That count is represented in the table with an "st." The highest percentage of student question is found in the authentic code. This is reasonable since authentic questions are ones in which the answer is not known. It is interesting to note that the teacher frequently relinquishes her power by asking authentic questions, thereby placing herself as a learner as well as students as learners.

Scaffolding. In spring of 2007, year two, and winter of 2007, year three, Mrs. G utilizes scaffolding at least 10 times per class period. This shows a great increase of undergirding of student understanding from the 5.7 and 2 counts in her first two observations, but then she has much fewer scaffolding episodes in her post project observation. Again, perhaps this is because the entire lesson is new material, and the students do not have as many interesting comments and questions as in other class periods.

Teacher press for involvement and teacher press for elaboration, explanations, and justifications. Mrs. G presses her students for explanations and justifications of their comments, more so in the first and last observations. She also uses many verbal cues to keep her students involved in the lessons. Figure 4.1 presents a list of a variety of prompts that Mrs. G uses to engage her students in meaningful discourse such as the previous examples.

Number one. What do the flat parts of the graph represent? Dick.
What does the section from 12 p.m. to 1 p.m. represent? Ivan, what do you have?
Who wants to volunteer to draw that?
Do you have your graphs done?
Let’s try that one. Where are my volunteers?
Casey, do you have that one done? Dorothy, what do you think?
Harvey, want to try?
An input number. Carla.
Somebody else give me a number? Tyler?

Trey, what do you think?

Teresa, what do you think?

I'll talk about that as soon as you think about it first.

Okay. Leslie, what's the second one look like?

Who's going to send it?

Okay, let me ask you a question, Kevin.

Who wants to do the last one?

Who hasn't given me one yet? Sarah?

Something else, Jacob?

So, talk to me about this one compared to the other two. Say something about that line. Carla, just say something. There's no right or wrong, I'm just asking you to make an observation.

I want to hear from Brandon.

But talk to me…

I want to ask Monica because she's falling asleep, and I want to wake her up.

Dray, can you read to me what number 28 is?

What's 31, Tyler?

32, Logan. What did you get for 32?

Okay, how about 33? Shenika, you were one of the few people for 33.

Regan, have you contributed here or not?

36, Logan.

And 37. Casey, what's the equation?

Step 1, Matthew, what was your first step?

Will you come up? ____ answers. When I call on somebody to give an answer, I want to hear from everybody whether you agree or disagree with that answer.

Who can finish it from there? Can you finish it from there?

Okay, 63. Becky.

65. Jonathan.

Okay. Andrew, 67.

Gary.

17 people were ____.

Back to 67. Somebody who disagreed, can you tell me what you got for an answer? Dave, since you brought it up.

All right, so now 71, Allen.

Jacob?

Dan, did you disagree?

I don't think it's right. Darin.

Allen, take me through the steps.

73. 2N-3… Matthew, do this one for me.

Who has not entered their quiz into the calculator?

14-15 people. Are the rest coming? 17. Where's everybody else?

Somebody want to help him? Pam.

So, Jed, if it started out as 8 inches, what is now the length of the new cube?

So when you subtract it, 1000 – 512, what did you get, Jay?

6 minus the sum of R and 3 is less than 15. Gary?

48. Hannah

Okay. 49. Stacy.

Okay, talk to me about what the word maximum means. Jonathan.

Nicole, will you answer that?

Jacob, can you answer it? What is it?

How is she going to earn that money? Allen?

That's okay, I'm asking you anyway, especially because you didn't do it.

Hannah, want to read the first one?

Kathy, can you do the next one?

Evan, can you do the next one?

Then we have one more? Jonathan?

Tyler, what form is this in?

Chelsea, can you do it for me?

And number 10? Matthew, did you get 10 right?

Just tell me what it is and then I'll tell you.

What is the Y intercept, Adam?

Ming. What's the Y intercept for that one?

So Ming, what's the slope of this line?

Stacy, can you repeat what I just said? Can you?

Jacob, what's the first thing that we did? Katie? Continue please.

Kaylin, next.

And I'm suspecting there are some people who are not even putting it in because I only have 11 people.

And I need for you to talk to me about it.

Ming, talk to me about…

Tyler, did she copy it right?

First of all, Tyler, I'm picking on Tyler today, I don't know why.

Dexter, can you give her A prime?

So how do you get there? Dexter?

Lindsay, you didn't get it?

What should it be, Lauren?

Twelve of you, ah….

Who wants to talk about this one?

Justin, you think you know how to do this?

I'm going to give Tyler the question again.

How come I don't have more negatives here? I see positives.

How are yours classified, Harry?

John?

Come on, I need more people. Let's go.

I want Lauren to have a chance to think.

Come on, Lauren. If C is cost …

Tyler, you were working on this one.

What's the domain?

You don't know what domain and range means?

Tyler, in this case, are what?

Figure 4.1. Prompts Mrs. G uses to engage students

Figure 4.1 delineates multiple strategies Mrs. G uses for engaging students in the learning community. It is a collection of comments from all classroom observations that demonstrate her insistence that all learners are engaged. Occasionally, she simply calls a student's name and requests information, but the table shows that Mrs. G varies her techniques for pressing students. She does not only call on students who have hands raised, but she utilizes the TI-Navigator™ to maintain student involvement as evidenced by comments such as, " I only have 11 people…where's everybody else…you were one of the few people who did number 33…somebody who disagreed [from a quick poll]." She also intentionally included students who are not meaningfully engaged in the task at hand without embarrassing them. Comments such as, "Come on, your class is counting on you…I know you didn't do it, that's why I'm asking you now…Monica is going to sleep!" cultivate a safe environment for students to re-engage in the classroom tasks.

Comment and question directionality. This is a combination of the question and comment constructs from the table 4.1 addressing all instances in which the teacher makes a comment or question to a student (T-S MC, T-S MQ) a student makes a comment or question to the teacher, or another student.(S-T MC, S-T MQ, S-S MC, S-S MQ). An interesting observation is that Mrs. G's students make many times the comments that she makes; however the words per comment are quite a bit fewer for the students, indicating that their comments are probably not as sophisticated as those of the teacher. In year one, winter of 2006, the students make 72 mathematics comments to the teacher, and the teacher makes 29.14 mathematics comments to the students. In this case, the students make 2.47 times the number of teacher comments. In year one, spring of 2006, the students make 1.53 times the number of teacher comments. In year two, spring of 2007, this number jumps to 3.07 times the number of teacher comments; and in year three, winter of 2007, nearly four times the number of teacher comments. In year three, winter of 2007, the number is reduced to just over twice the number of teacher comments. Note that in IRE, the response is always coded as a student-to-teacher mathematics comment; however, her low levels of IRE would not account for a great percentage of the student-to-teacher comments, ranging from 11.5% in case 2 to 20% in year one, spring 2006 . These percentages were calculated by dividing the number of IREs in that case by the number of student comments. Likewise, the teacher-to-student questions are somewhat accounted for in IRE, but only ranging from 22.8% in year one, spring 2006, to 28.5% in year one, winter 2006. These percentages were calculated by dividing the number of IREs by the number of teacher-to-student questions. The student-to-student comments and questions may not be adequately represented by the count on this chart because the students had time every day that they worked at their desks on a warm up, reviewing homework or exploring a new idea, and took advantage of discussing something quietly with a neighboring student. These instances are seen on the video tapes, but are not audible, so did not appear on the transcripts; therefore, these comments were not counted.

Teacher talk. These counts may seem high for comments not related to mathematics, but they include repeating a question or brief aside comments such as, “Where is my pen?” or “I thought I started class.” They are fairly brief comments ranging from 7.71 words per comment (wpc) to 13.47 wpc.

Formative Assessment

After the principal investigators and T^3 instructors spent some time in the professional development sessions establishing the importance of discourse, the next big idea was, what does one do with the knowledge gained from listening to the students? There are key reasons to providing an environment where students can speak freely about the mathematics they are learning. One is that as learners are encouraged to formulate their ideas well enough to verbalize them, they are, in essence, forcing themselves to make sense of the mathematics they are doing. They also see that other students have similar misunderstandings or different ways to view a concept. Another key reason is as students expose their ideas, they also expose their misconceptions. Once the misconceptions are brought to light, they can be rectified. The following section identifies specific citations from the professional development sessions that encourage participants to utilize their knowledge of student understanding for formative assessment.

CCMS Professional Development on Formative Assessment

These are excerpts made by principal investigators Dr. Loius Abrahamson and Dr. Stephen Pape from the summer institute at The Ohio State University prior to participants' initial use of the TI-Navigator™ highlighting instances that they may the new technology for formative assessment.

> LA: From the assessment centeredness point of view, we found that with formative assessment actually give feedback to students we can reverse... and also the teacher gets feedback from these kind of systems, so you know after you've taught something whether they've got it or not. And if they haven't got it, you kind of find out why they haven't got it. It also allows you to have an environment of knowledge centered where you can really focus on understanding. If you teach something and they don't understand, you can go back and redo it.

SP: So you have this information, and you have to think about which road to take. One of the questions we have in the research is about the critical junctures in a lesson when you use the Navigator. So when will you make that decision in a lesson about when to use, like the Quick Poll? Nothing preplanned; but you're noticing something, and you say, "Oh, let me get this data." So, how do you make decisions to use the Navigator? Preplanning as well as online, I think that's going to be interesting, and perhaps it makes your job somewhat more complex. You're going to ask questions, right? We always ask questions, but we're getting that information back.

In the professional development sessions at the T^3 International Conference in Denver, Dr. Stephen Pape challenges teachers to talk about the ways in which teachers are using the feedback they are getting and presses the participants to support student understanding with the feedback.

SP: In what ways has the Navigator supported your students' understanding? Let's hear it from you. In what ways have you found that your students are learning differently or more?

P: I think in my classes, it's the instant feedback, and they really want to see how everyone is doing.

SP: Okay. How many see the feedback as one of the most important components of the Navigator?

[A majority of participants raise hands]

SP: That's instant feedback, eh? In what way? Let's delve into that further, and talk about what to do with the feedback and how do you support their understanding through that feedback. Yes, they receive it, but what do you do with it? … Or how often have we asked a question, one person answered? We have evidence from our classroom observations where people are doing other things because they just looked at a Quick Poll. ... How many have had that, where they have had to slow down a little bit because they have learned something about their [students'] knowledge?

Mrs. G's Comments about Her Perception of Formative Assessment in Her Classroom

In telephone interviews throughout the CCMS Project, Mrs. G was questioned about her use of formative assessment. The following are excerpts from interviews where she discusses her concept of utilizing formative assessments:

> First year, spring 2006:
> Lessons are more interactive than before TI-Navigator™. Having an understanding of their knowledge gives you an ongoing assessment of them which allows you to plan your lesson based on your assessment of where they are rather than moving forward and assessing every third day or so as I traditionally would.
>
> Second year, fall 2006:
> In the middle of class, I'll change, and I'll stop if I'm doing Quick Poll or Screen Capture and see students aren't getting it. I'll stop, and I'll change and re-explain or do more examples or whatever. I had a student tell me the other day that she really appreciated that I didn't move on until the students understood it. She had a teacher last year who just seemed to teach it and say, "Okay, you need move on," and she didn't get it, but she felt like she was getting it this year. It helps me assess in the classroom and I'll slow down or speed up depending.
>
> Second year, spring 2007:
> [I was doing a] Screen Capture before end of course exams and the question was, "Which of these sets of points is linear?" and this boy was taking the *x*, *y* coordinates and multiplying them together … what in the world was he thinking? The kids who are really quiet in class and don't want to say anything, don't want to share, but when you can do Screen Capture and see what they're doing, it just helps you understand how they're thinking. During instruction, well, since it allows me to easily assess students' knowledge there are times I can pick up the pace when I wasn't planning to, or just the opposite, have to slow it down so students can learn.
>
> Third year, fall 2007:
> You can instantly see those kids who are struggling and don't have the concept.
> During instruction, the minute you see the majority of the class is getting whatever it is you're teaching, which you don't get without TI-Navigator™. You can make adjustments, re-teach, think about presenting it in a different way, whereas before TI-Navigator™, you just went on

> until you gave that quiz and then found out half the class didn't get it. Every day no matter which facet of TI-Navigator™ I'm using, [I'm] getting input from almost [everyone. . . The technology follows with the communication for the majority of the students. You just can tell immediately. It doesn't matter what the topic is. You can find who's understanding and who isn't, and address it immediately and correct their misunderstanding immediately

According to Black and Wiliam (1998), an essential piece of formative assessment is instantaneously changing lessons to accommodate student learning as their needs become evident. In post observation interviews, I asked Mrs. G if she changed her plans for the lesson that day during the course of the class period. Her responses from post-observation interviews are overwhelmingly affirmative.

> *First year, winter 2006*:
> Mrs. G: I taught the material yesterday. They weren't as comfortable as I wanted them to be. I was shocked that there was still so much work to do because my plan was to go on to some word problems.
>
> I: How do you make those decisions of those times that you haven't planned it, but you use Quick Poll?
>
> Mrs. G: Deer in the headlights. I felt like I had explained this topic inside out and backwards, and I posed a question in Quick Poll and I thought, "Oh my goodness! Let's back up and try again."
>
> I: Given what you taught yesterday, what decisions did you make about today?
> Mrs. G: After class yesterday. I can't write a plan in advance. I mean, it changes.
>
> I: How have you taught the lesson differently in the past?
>
> Mrs. G: I would have not known that they needed more practice until I gave them a quiz.
>
> I: During the course of teaching, did you change your plans today?
>
> Mrs. G: Yes
>
> I: I think I saw exactly when you did.

Mrs. G: I spent a lot more time on those homework problems than I ever intended to.

First year, spring 2006:
I: Tell me about your plans.

Mrs. G: We backed up from what we originally planned because after taking a quiz I realized the kids were not ready to write equations of lines from scatter plots. Well, some of them, those 5 who got it, they're solving system of equations right now.

Mrs. G: Sometimes I think I don't give them enough practice. We do some homework and some TI-Navigator™, and sometimes I think they need more practice, doing it over and over again.

Second year, spring 2007:
Mrs. G: I try to get as much student involvement and feedback as I could. I could get a better picture of how they were doing.

I: …without TI-Navigator™?

Mrs. G: I would have just read off answers. I love having the graphs up there.

I: So you would have read answers, and then what?

Mrs. G: I would have asked if anyone had any questions. Doing with TI-Navigator™ ,[I] know who to target.

Third year, winter 2007:
Mrs. G: Navigator gets everybody involved. There's no question about it. Being engaged is supporting their learning.

I: During the course of teaching, did you change your lesson plans?

Mrs. G: Yes…when I decided to whip out that TI-interactive calculator [ie: TI- Navigator™]. I hadn't planned that. I could see they were struggling.

Evidence of Formative Assessment

I attempted to code formative assessment into NVivo using the following definition: Assessing student knowledge during the course of the lesson with intent to modify the lesson as needed. Checking homework for understanding, diagnostic uptake, Quick Polls, Activity Center and Screen Capture may be indicators of formative assessment. Since intent cannot be determined from observing class and coding transcripts, in an interview with Mrs. G, I asked her about several instances that I suspected were for the purpose of formative assessment. My question was, "What might have been the purpose of this statement/question/activity?" Mrs. G consistently responded that she was determining what the students knew so that she could offer remediation, or move on. My initial idea was to code all like instances as formative assessment.

As I began to attempt to quantify these instances in NVivo, it quickly became evident that very large blocks of transcripts were coded as formative assessment in every lesson. It was clear that quantifying formative assessments in Mrs. G's classroom would be nearly impossible because diagnostic discourse permeates her lessons. For this reason, it is not feasible to mark a beginning and end to a formative assessment episode. Her typical lesson plan is a common warm up, homework check and exploration of new ideas. However, the implementation of this plan is increasingly less traditional.

Class periods consistently begin with students solving warm-up problems while Mrs. G checks student's names for completing their homework. The warm-up questions are typically review problems, sometimes from a bank of questions to prepare for the state exam. After the initial homework check, Mrs. G explores student responses to warm-up questions, commonly with a great deal of uptake, as seen in previous examples.

Following the warm-up exercises, Mrs. G will have a homework questioning session. She varies her homework checks. Some examples are a quick poll with agree/disagree, graphing functions in activity center and simply asking students what their questions or concerns are. Because the norms of her classroom are about student learning, students do not seem to be timid about asking their questions. This homework time is diagnostic as well. Mrs. G encourages students to identify their misconceptions by pressing them to elaborate on their responses and insisting upon involvement.

After the homework analysis, Mrs. G provides a time for students to explore new ideas or to revisit the previous day's topic. Formative assessment is employed during this time by use of screen capture or activity center. She also makes use of less technical devices such as a "plastic communicator" whereby students graph their functions on an erasable surface such as a transparency and hold them up for the class to see.

In year one, spring 2006, Mrs. G's students did not do as well on a quiz as she expected. In this case, the quiz was intended as a summative assessment, but she used it as a formative assessment. She worked with her students to highlight common errors on the quiz and gave a re-take of the quiz on the following day. She was still concerned about the misconceptions of a majority of the class; so this time, she set aside five students who scored 10 out of 12 or higher to move on, while she spent more time with the other students who were still struggling.

Final Observation

The last day I visited Mrs. G's class was day two of a two-day observation in June 2009. This was a post project observation to compare her implementation of the constructs highlighted in CCMS professional development sessions with her implementation of them during her time in the project. It is significant that on this day, the students were involved in a review game that extensively incorporated all three of the constructs identified in this case study: classroom discourse, levels of questioning and formative assessment. Mrs. G explained the rules of the game to me in her post observation interview:

> Mrs. G: The rules of the game were that, there were problems taped to the board, there were different little levels of problems: very easy, medium, and difficult. For the class that you saw, which was an honors class, I had them working on the medium and the difficult problems. It was a betting game, so they were put in groups, and they would work a problem, betting, they had $5 when they started out, and they had to–they bet with that money, that they could do that problem. And once they did the problem, they'd come up to me, and if it was right I paid them, one-to-one and two-to-one for a difficult problem And so, there was one person in the group who was responsible for coming up and getting the problem, deciding, not deciding on the bet, but talking to the group, so that I was only working with one person. You know, or actually I guess, I had 5 groups, so 5 people coming back and forth to me. They all had to show their work, and then, the group that won is going to get 5 bonus points added to their test tomorrow, and then the second place group got 4, and then 3, and then 2.
>
> I: Okay. I see. So placement, I heard them discussing the placement so I see why that matters. What benefit does this game have on student achievement versus other forms of review, do you think?
>
> Mrs. G: They are definitely all more involved in doing the problem and making sure they get it right. And there are times—they realize that sometimes the quiet one that's sitting there might have the right answer, and the other 3 of them didn't have the right answer, and then they all need to start listening to that quiet one and have that one contribute to the group as well. I think there is much more student involvement then, and they're happier when they're working than if they're just, you know, if you and I are going over problems on the board.

Beliefs and Attitudes Survey

The participants in the CCMS Project completed a beliefs and attitudes survey periodically during the course of the project. In this segment, I compare the survey that Mrs. G completed early in the project at the beginning of year one in the fall of 2005 with one she completed in the spring of 2007 at the end of her second year in the project. The results of the surveys little change in Mrs. G's beliefs and attitudes during her tenure in the project. However, it seems that her beliefs and attitudes are aligned with the pedagogy supported by the professional development sessions offered by CCMS.

In both surveys, Mrs. G answers that she is fairly familiar with the National Council of Teachers of Mathematics (NCTM) Standards. She agrees with the overall vision of the mathematics education described in the NCTM Standards, and she has significantly implemented recommendations from the NCTM Standards in her mathematics teaching.

Mrs. G also shows consistency in her beliefs regarding classroom discourse. The survey poses two scenarios, and participants are asked to align themselves with one or the other. The scenarios are as follows (Teacher Practices and Beliefs Survey):

> Ms. Hill was leading her class in an animated way, asking questions that the students could answer quickly; based on the reading they had done the day before. After this review, Ms. Hill taught the class new material, again using simple questions to keep students attentive and listening to what she said.
>
> Mr. Jones' class was also having a discussion, but many of the questions came from the students themselves. Mr. Jones could clarify students' questions and suggest where the students could find relevant information, however, he couldn't answer some of the questions himself.

On both surveys, Mrs. G responded that she is more comfortable having a discussion like Mr. Jones's class, but that most students preferred a discussion like Ms. Hill's class. Mrs. G also responds that she thinks students gain more knowledge in a class discussion like Mr. Jones's and that she thinks students gain more useful skills in a class discussion like Mr. Jones's. Mrs. G's beliefs and attitudes regarding Mr. Jones's class are reflected in her classroom practices. Table 4.1 shows that students contribute questions and comments regularly. Additionally, it shows that Mrs. G poses as many as 43 authentic questions in a class period. These are questions without a known answer, so

Mrs. G is clearly comfortable in a classroom discussion where the answers to all of the questions are not pre-scripted.

It is interesting that Mrs. G shows a slight decrease in her perception of classroom discourse. For instance, Mrs. G reported in fall of 2005 (prior to year one) that she engaged the whole class in discussions about incorrect responses in all or almost all mathematics lessons. Two years later she reported that she engaged the whole class once a week indicating a drop in her perception of engagement. Mrs. G reported in fall of 2005 that she requires students to explain or model their problem-solving strategies in all or almost all mathematics lessons, but two years later she reports more than once per week (but not all lessons). This decrease is a surprising response since Table 4.1 shows the highest use of uptake of student questions and comments in spring of 2007 and a steady increase in teacher press for elaboration of student comments throughout the project. It is also interesting that during the stimulated recall interview in the summer after the final observation, Mrs. G was viewing tapes of her classroom. She commented that she did not realize that there was so much discussion in her classroom. Perhaps her expectation of classroom discussion increased during her participation in the project, and her perception of the discussion in her classroom did not meet her expectations, so she reported lower discussion and engagement on the survey.

Following year two, Mrs. G changed her opinion on collegiality during the two-year period between the initial survey and spring of 2007. In the initial survey, Mrs. G disagreed with two statements regarding sharing ideas, but two years later, she agreed. The statements are, “My colleagues and I regularly share ideas and materials related to mathematics teaching,” and “My colleagues and I share ideas and materials related to use of educational technology to teach mathematics." After Mrs. G left the project, she did not take a survey, but she volunteered similar information to me. Regarding sharing ideas about technology, she reported that her new school was technology poor, and she wrote a grant to purchase the TI-Navigator™ and train the faculty to use it. Regarding sharing ideas related to teaching, Mrs. G stated that her new school requires departmental meetings. She told her new colleagues that she was adamant about the notion of formative assessment, and she would not move on to new topics while a majority of the class was struggling with current material, even if it meant excluding topics that she deemed to be less important. Evidently, this was the focus of several tense meetings. Her new colleagues insisted that she adhere to the timeline of the pacing guide. They eventually invited the principal to attend one such meeting, but Mrs. G would not budge. When the state test scores for her students outshone those of the opposition, there was no more talk about pacing guides!

Naturally, the initial survey does not have questions regarding the impact of the TI-Navigator™. In the spring of 2007, Mrs. G responded to survey questions reported in Figure 4.2 regarding the impact of the TI-Navigator™ in her classroom. The responses are strongly disagree (SD), disagree (D), neutral (N), agree (A) or strongly agree (SA).

Using the TI-Navigator™ does not help improve student understanding: SD

Class discussions are not helped by the use of the TI-Navigator™: SD

I would know just as much about student understanding if I never used TI-Navigator™: SD

There is a greater sense of togetherness with people in this TI-Navigator™ than in other clases: SA

The TI-Navigator™ helps me tell if students understand a concept: SA

Students are more actively engaged in a TI-Navigator™ class than in others: SA

The TI-Navigator™ makes no difference with regard to students' efforts in answering questions: SD

There is no advantage in using the TI-Navigator™ to help students learn in this class: SD

When I use TI-Navigator™, the students try really hard to answer questions: A

Students are less on task in TI-Navigator™ classes than they are in other classes: SD

Using the TI-Navigator™ does not help in letting students know where they stand on a question: SD

Using the TI-Navigator™ students can often tell whether or not they are right or wrong: SA

Doing activities in class with the TI-Navigator™ helps student relate new material to things they already know: SA

Using the TI-Navigator™ does not improve the feeling of togetherness in class: SD

Figure 4.2. Mrs. G's responses to survey questions about TI-Navigator™ use

One of the research questions of this study is: What aspects of Mrs. G's work could be attributed to the project? In the last section of the survey as reported above, Mrs. G believes the TI-Navigator™ has made a positive difference in her classroom environment. She reported that students are more on task; that there is a greater sense of community; students can assess their own work; she knows more about her students' understanding; there are more class discussions; and students try harder as a result of her use of the TI-Navigator™. Mrs. G consistently reported that the CCMS Project did not present her with new pedagogy or philosophies, but it is aligned with her belief system. The results of the beliefs and attitudes survey confirm her perception.

Mrs. G's Views on Professional Development

In the years I worked with Mrs. G, she mentioned occasionally that professional development from the county was forced on the teachers. She gave two recent examples of professional development plans from her school system. One was called "Plan, Study, Do, Act." It is a fill-in-the-blank reflective procedure for the class in which students and teacher complete forms and post them in the classroom. The forms require the current topic, the collective student test scores, and a plan of action for the next unit. Mrs. G did not disagree with the theory behind it; however, since the plan was not formative, rather summative in nature, she questioned the formality of it and its usefulness. Being a reflective practitioner of her own accord, she somewhat resented having to fill in someone else's blanks. The other program that she had been required to participate in recently was called "L to J," and it was named for the idea of changing an L shaped graph (decreasing test scores) to a J shaped graph (increasing test scores). She remarked that teachers attend these mandated workshops and then return to their classrooms to teach the way they want to. Summarizing her attitude toward teaching public school, Mrs. G references a Catholic school principal who says, "The problem with public education is they get on a bandwagon, and they swing one way to the left, and then they swing one way to the right, and they are never in the middle." She claims that workshops such as those mentioned above are presented as magic to change everything and make students learn. What is needed is a real focus on how students are learning and then support that with professional development. She questions trendy ideas such as the seven-point lesson plan, humor in the classroom, and "this, that and the other" and asks, "What does all that have to do with students learning and understanding?" In my final interview with Mrs. G, I asked her to comment on her experiences with professional development in which she has been involved.

> Professional development needs to be relevant to your profession. [As a mathematics teacher] I am looking for professional development that is relevant to me. How can I use this in the classroom? And how is this going to improve student learning and understanding? Because, those are

> my goals. My goal as a teacher is…to have students understand what I teach them. The generic professional development that gets handed down through the county, such as the PDSA, is just a process that I didn't see the relevance for. It was time consuming, and I did not see the relevance for it in my classroom. Whereas, I sought out the Navigator Project because I saw Navigator as something that would help me understand student learning and improve student learning. It was going to be a motivator for students. It was going to allow students to talk more about math, so that professional development was meeting my goals and my requirements for teaching mathematics. The professional development sessions we had at Ohio State and Denver and other places were all research based. Nobody was saying "you have to do it this way." The way it was presented allowed you as a professional to choose whether or not it was [going to be useful in your classroom]. There have been other professional developments that I have chosen to do that I felt were beneficial…like Hands On Algebra.… They are probably geared more toward my style of teaching, and that is why I gravitate towards them: investigative, discovery, hands-on approaches to learning math. [Mrs. G, 2009]

Summary

In this chapter, I have presented an analysis of observation data related to classroom discourse, questioning and formative assessment and the analysis of Mrs. G's responses to a beliefs and attitudes survey. The results showed that she believed that classroom discourse is a key element in supporting student understanding. Overall, Mrs. G is observed to promote genuine discourse/discussion in her classroom, and to promote student engagement. She uses a variety of strategies including multiple questioning techniques to encourage her students to verbalize their ideas. By students sharing their knowledge with the class, misconceptions are readily addressed. Mrs. G utilizes formative assessment and immediately provides remediation for faulty ideas, continually re-thinking her preconceived lesson plans to accommodate student learning. Students are encouraged to add to the knowledge base of the classroom by sharing their innovative ideas, thereby cultivating a rich discourse that is preferable to thin lecture found in many traditional classrooms. In the next chapter, I will take heed to Mrs. G's words in conjunction with the evidence of her implementation of the professional development she received as a participant in a project she longed to join.

CHAPTER 5

DISCUSSION

Summary

Encountering a seasoned educator who has spent her career finely honing her skills, yet maintains the zeal and enthusiasm of a green teacher prompted me to further investigate this practitioner whom anyone would want to emulate. I needed to learn as much as possible about her quest. Initially, as a researcher for the Classroom Connectivity in Promoting Mathematics and Science Achievement (CCMS) Project based at The Ohio State University and because of geographical proximity, I was assigned by the principal investigators to collect data in Mrs. G's classroom. My task was to videotape her class sessions as she implemented the use of new technology in her teaching. She was a self-selected participant in a project that was evaluating the effectiveness of the TI-Navigator™ , a wireless communication system. As I made observations, I became intrigued by the climate in her classroom. Students seemed to be inquisitive and engaged. They freely communicated among themselves. It was a lively classroom with little opportunity for students to sit idle and uninvolved. Students who attempted to escape learning were quickly called back into the community with comments such as, "Your class is counting on you!" Mrs. G used the TI-Navigator™ on a regular basis to generate discussion and assess her students' knowledge. The calculator was a new addition but I wondered how many of her classroom practices could be attributed to her participation in the CCMS Project and what could be learned from studying her teaching.

Mrs. G is a seasoned teacher with years of teaching and learning experiences, so it is an impossible endeavor to identify exact instances that she incorporated CCMS Project professional development into her classroom practices and credit only the project with that particular episode. I cannot know that she may have done the same thing without being involved in the professional development offered by the CCMS Project. However, this classroom presented an opportunity to make a thick description of an effective environment where students were actively learning and engaged in meaningful discussion. So, I took advantage of this opportunity to do a case study attempting to align this rich learning environment with the suggestions and collective efforts of the professional development sessions of the project. Three constructs were the focus of the study: classroom discourse, levels of questioning and formative assessment I viewed tapes of professional development sessions, highlighting instances where these constructs were explicitly addressed by principal investigators, Teachers Teaching with Technology (T^3) instructors, or participants. I then reviewed telephone interviews and post-observation interviews to identify data points in which Mrs. G believes she implements the previously mentioned pedagogy and finally looked for evidence of these constructs in her videotaped classroom observations.

Conclusions and Discussion

The research questions for my case study are: what effect did the professional development Mrs. G received in the CCMS Project have on her classroom practices in the areas of classroom discourse, levels of questioning and formative assessment? What aspects of her work could be attributed to the project? What could be learned from her classroom to further inform teacher preparation and professional development? I will discuss the first two questions in conjunction with the literature. The third question will be discussed in recommendations for practice and future research.

What effect did the professional development Mrs. G received in the CCMS Project have on her classroom practices in the areas of classroom discourse, levels of questioning and formative assessment? Mrs. G did not recall learning new pedagogical strategies from the CCMS professional development sessions; however she consistently remarks that the PD offerings supported her goals of student understanding. Because learning is a complex, lifelong undertaking, it is impossible to delineate which aspects of Mrs G's classroom practices can be directly attributed to the professional development sessions provided by CCMS. However, because the pedagogical strategies of classroom discourse, levels of questioning, and formative assessment are directly addressed in the professional development sessions, and Mrs. G specifically refers to them in light of the professional development sessions and her new technology in her interviews and demonstrates each construct in her classroom practices, I conclude that the professional development had an effect on Mrs. G's pedagogical strategies. She responded to the work sessions positively in her words, and there is evidence from her classroom observations that she implemented the pedagogy.

What aspects of her work could be attributed to the project? During telephone and post-observation interviews, Mrs. G reported that using the TI-Navigator™ supported student understanding in a number of ways. The connected classroom raised a much greater awareness for herself and her students of misconceptions. This awareness increased classroom discourse as she and her students openly discussed the origins of incorrect responses and reconciled them. Mrs. G reported that she had always had a concern for the students who may be left behind because their voices were not heard. She is satisfied that as a result of using the TI-Navigator™ most-to-all student voices are heard. Mrs. G claims that her students are talking more and that increases student learning. She believes that there is a greater sense of community among her students as a result of visible mass responses.

The literature purports that in order for professional development to produce teacher change, the practitioner's belief system must match that of the suggested program and the probability of this is much greater when the teacher has a choice in her learning experiences (National Research Council, 2000; Romberg, 1988; Sowder, 2007; Thompson, 1992; Warfield et al., 2005). This was the case with Mrs. G, a self-selected participant in the CCMS study. Being accepted to participate in the project meant a lot to her, as evidenced by an emotional recollection of being initially excluded from the project by a restriction to ninth grade algebra teachers. She is also a high implementer of the pedagogy and technology supported by the professional development sessions. In the following sections, I compare the results of this study to the selected readings in the literature review from chapter 2 of this dissertation. I am focusing on three major areas: the teacher's perception of herself as a learner; the environment in which the teacher works; and the professional development offering itself.

Teacher as Learner

The literature review from chapter two of this dissertation is laced with indicators that in order for change to take place in a teacher's classroom practices, one must view herself as a lifelong learner. P. Mark Taylor refers to the "inertia" concept that teachers who view themselves as learners are likely to continue learning, and those who view themselves as having already completed their learning in an undergraduate program are likely not to continue learning (Taylor, 2002). Teachers who volunteer for professional development programs typically believe that the program will enhance their teaching and that willingness leads to change (Hyde et al., 1994). Clement and Vandenberghe (2000) refer to self-motivated teachers as "progressive professionals" who automatically deem themselves accountable for work in their classrooms (Clement & Vandenberghe, 2000). They will seek out and implement innovative practices that enhance student learning. Recall the Italian equivalent of action research called *Nuclei di ricerca didattica* (Nuclei of didactic research) in which there is a brief, but fruitful, tension as the teacher becomes the researcher and embarks on a journey of awareness and personal growth (Malara & Zan, 2002).

The teacher's attitude about herself as a learner is a predictor for the degree to which she seeks new opportunities for learning. Mrs. G's desire for learning about herself and her students is evident throughout the project. She would often ask about viewing the tapes of the classroom observations for her own analysis. As I was packing to leave her classroom after observations, she would often ask me, "Is there anything that you can see that I should be doing differently?" When I met with her for a stimulated recall interview accompanied with her tapes and transcripts, it was difficult to get her attention initially because she was analyzing her own work! Following student focus group interviews, she was eager to know the students' ideas about learning with the TI-Navigator™, not a self-serving question of, "Do my students like me?" She casually reported to me on one occasion that she was certain that her husband was tired of her coming home every day and asking the same question, “What can I do differently to reach my students?”

Mrs. G was notably moved by being accepted into the CCMS Project. Her words, “Learning sets people on fire,” were followed by a genuine appreciation for being involved in such a large project and studying with knowledgeable people in the field of mathematics education. There was no separation of the theorists and the practitioners. She intensely spoke about her initial fears of not being accepted because she taught middle school, and the principal investigators were seeking high school algebra teachers. In my final interview with Mrs. G, she summarized her determination to become involved in the CCMS Project. After a detailed description of her diligent search for a grant for the TI-Navigator™, she recalled her fears of being left out of the project indicating how desperately she wanted to participate. “I was nervous that I wasn’t going to get accepted because they wanted algebra one teachers from high school in the beginning. They weren’t taking any middle school, and I was middle school.” As Mrs. G’s last statement trails off, she becomes emotional. Clearly this is an important gauge of her willingness to participate fully in the CCMS Project once she was admitted.

Professional Environment

The environment in which a teacher is practicing greatly informs the extent to which she is a motivated learner. Judith Sowder (2007) reminds administrators that “. . .schools will not be improved for children unless schools also become places for teachers to learn.” Clement and Vandenberghe (2000) reiterate this paradigm with the notion of teachers as professionals creating their own learning spaces. The professional environment is particularly important among adult learners. An authoritative system is non-productive for adults. It is necessary for all parties to contribute to critical thinking and learning, not solely the novice (Jacobs, 1998; Nyikos & Hashimoto, 1997).

Mrs. G makes this one of her points in my final interview with her when she comments that in the professional development sessions offered at The Ohio State University, one of the T^3 instructors refers to the lessons as guidelines. It is important to Mrs. G that nobody says, "You must do it *this* way." It is interesting that in her Teacher Practices and Beliefs Survey, Mrs. G reports that prior to the project her school's principal did *not* provide support for her professional decisions on how to assess learning. After year 2 of the CCMS Project in spring of 2007, her perception of this question is that she strongly agrees that he does. Furthermore, she consistently reports that her principal supports her innovative instructional practices.

Later, at her new school, she had conflicting views with her department regarding the pacing guides that prescribed adherence to a predetermined schedule. She maintained that she would not move on to a new topic while a majority of students continued to struggle, even if it meant eliminating a less important topic. Even though she initially did not have the support of her colleagues nor her principal, she had the confidence to persist with her convictions, and gained their support after a semester of successful test scores. Perhaps this is a cyclical phenomenon in which the teacher who experienced administrative support and was given some autonomy in decision making was allowed to blossom as a teacher in her own right, thereby further gaining respect of her colleagues and administration.

Professional Development Offerings

Indicators that a professional development opportunity has been successful extend beyond a project. One assumption of success is that the participant carries out the suggestions of the professional development after she has left the project (Warfield et al., 2005). Unfortunately for CCMS, Mrs. G had to leave the project upon changing schools and leaving algebra one. However, she wrote a grant at her new school to receive the TI-Navigator™ and trained her new colleagues in using it. When I made a classroom observation at her new school, the pedagogy of classroom discourse, questioning and formative assessment were still highly evident.

Success is imbedded in the participants' beliefs and attitudes (Thompson, 1992). Although I did not find significant changes in Mrs. G's attitudes and beliefs about mathematics and mathematics education, she reiterated numerous times that the CCMS Project was aligned with her established educational philosophies, so she easily gravitated toward the suggestions for implementing the TI-Navigator™ and the suggested pedagogy of the workshops required for the CCMS participants.

Collegiality is an important issue in the success of professional development. Clearly, in order for knowledge to be socially constructed, participants must work with colleagues. P.Mark Taylor (2002) addresses the importance of collegiality in seeking another's help as well as offering to another what one has learned. Judith Sowder (2007) echoes this notion. Learning communities remain intact when its participants believe they are benefitting professionally. The National Research Council (2000) also recognized the immense importance of teachers teaching one another. Evidence that Mrs.

G's CCMS cohort had a strong bond is found in freely sharing ideas at conferences and on the Listserv. Participants assembled of their own accord at conferences to share ideas, as well as to engage socially. Following the final T^3 International Conference that the cohort attended as a group, they gathered for a group photograph and were nearly mournful for having completed their part in the project.

A comprehensive list of Clarke's (1994) principles for professional development can be found in the chapter 2 literature review of this dissertation and again with specific references to the CCMS Project in chapter 3. The T^3 instructors and principal investigators for the project incorporated these principles in their professional development. A brief list of highlights include enlisting administrative support, securing commitment from participants, offering ongoing support throughout the project, allowing time for change, allowing participants to share their successes and concerns in small and large groups and encouraging participants to continue to grow professionally. Mrs. G alluded to several of these principles during her tenure in the project. However, in our final interview she specifically stated that she would not have been able to remain in the project had it not been for the immediate and accessible technical support. A number of times she had issues with network connection, software and hardware, sometimes at critical moments in her class. She may have become discouraged and drifted away from the project had it not been for the immediate support she received.

Recommendations for Practice

Since the Russians surprised the world with Sputnik, the US education system has operated under a panic mentality to make US mathematics students more competitive on a global level. However, rather than focusing on student learning, the focus has been on teacher “fixing.” “The American approach has been to write and distribute reform documents and ask teachers to implement the recommendations contained in such documents” (Stigler & Heibert, 1999, p. 12). An “emphasis on correcting deficits rather than encouraging professional growth” is listed as an impediment to staff development sessions (Clarke, 1994, p. 41). The result is a most frustrating situation where teachers are not treated as professionals (Romberg, 1988), but rather bludgeoned with speakers, workshops, consultants, new curriculum, new materials, new math, new activities and an overwhelming offering of other potentially useful, but thoughtlessly mandated, programs. “The most common form of staff development…in the United States… continues to be the one-shot in-service seminar in which an external expert makes a presentation, with little active involvement and no follow-up” (Clarke, 1994, p. 42). Furthermore, “two thirds of U.S. teachers state that they have no say in what or how they learn in the professional development opportunities provided to them in schools” (National Research Council, 2000).

In an effort to offer continuing education to teachers, schools often provide short, discontinuous and irrelevant workshops. Hiring an outside professor or consultant is a popular method to provide these in-service programs because they are relatively inexpensive (Middleton, Sawada, Judson, Bloom, & Turley, 2002). A common scene in American public schools is all of the teachers gathered in the media center after hours with a consultant of sorts hired to come for the afternoon and address all the teachers simultaneously as if they all have the same concern. When in truth, American teachers are so overwhelmed with administrative duties, they do not have time to reflect on what their questions might be. At the root of change is awareness that there is a problem, but teachers do not have time to reflect on classroom practices; therefore, they are not likely to identify changes they would like to make. So, they sit in an after-hours workshop, and most of those who are still malleable enough to attempt implementation of the new knowledge that has been imposed upon them "often modify the features to fit within their pre-existing system instead of changing the system itself" (Stigler & Heibert, 1999, p. 98). Even when teachers feel that they are implementing reform, the overall system runs basically as it did before, and teachers become jaded. Then, the next time the opportunity comes along for teachers to be detained after hours for a staff development, they may think "Not another reform! I'll just wait this one out" (Stigler & Heibert, 1999, p. 100).

Current trends in education reform may exist as if there is some desired destination that once reached, the "reformed one" may rest on her laurels. Rather, the progressive tense of *reforming* is a more reasonable and desirable goal. Teachers are missing opportunities to learn how to continually refine their own practices and, even if given such opportunities, they have been conditioned that the only changes that are to take place are ones mandated by the building or district level administration. A doctor who only reviewed the latest research for a week every summer as mandated by his practice would soon not have many patients. Neither would clients continue to employ the services of a lawyer who studied the recent precedents at a yearly retreat. Yet, these are the typical professional development events that have been deemed sufficient for teacher growth.

Teachers who are *required* to attend professional development sessions often react with resentment and resistance to change (Hyde et al., 1994). "In spite of courses and workshops, teachers are likely to teach math just as they were taught… changes in requirements or improvement in curriculum materials alone are unlikely to alter this pattern" (Ball, 1988) These conventional methods of professional development are usually largely ineffective for a number of reasons. To bring in external, blanket assistance undermines many of the theories for learning.

In my final interview with Mrs. G, she makes emphatically claims that "Professional development needs to be relevant to [one's] profession." Further, she asserts that she chooses professional development opportunities that are aligned with her goals for student learning. It follows from the literature and Mrs. G's comments that teachers must be allowed to have a choice in which professional development opportunities they will take advantage of. However, there may be many in this profession who have chosen it for their passion for teaching and not a passion for learning. The latter must be cultivated in pre-service teachers. It is possible that many teachers do not know how to choose appropriate professional development for themselves because the expectation is that they will be told what to do. In order for in-service programs to be effective, pre-service programs must incorporate the expectation that its graduates will continue to seek appropriate learning opportunities for themselves. Pre-service teachers must be educated in the opportunities available to in-service teachers and must leave their programs armed with a plan to continue their education in an area that is relevant to them. Perhaps assertive teachers with a plan will be less likely to fall prey to generic sweep of stagnating workshops.

Recommendations for further research

This dissertation is a case study of one exemplary teacher. However, as I viewed and analyzed tapes of other participants for the project, I noticed that there are some participants who did not immerse themselves in the CCMS Project as Mrs. G did. There were a few participants who reported that the TI-Navigator™ did not make a difference in their classroom practices or the learning environment. In the professional development sessions, there was one participant who insisted that the TI-Navigator™ took too much time in her classroom. So, why do self-selected participants who attend identical professional development sessions respond differently? Perhaps some initially viewed the new tool as the "silver bullet" that was mentioned by Stephen Pape, one of the principal investigators, in several of the meetings with participants. Perhaps they were looking for a quick fix and not interested in making changes themselves. Perhaps the participants who did not appear to be as interested in the project as Mrs. G actually did make changes in their practices, but they did not distinguish themselves as a phenomenon because they are at the embryonic stages of change. This does not make that teacher change any less valuable. Quite the contrary, since often the hardest part of changing practices is an opportunity to begin. Looking in depth at some of these participants could add to the knowledge base regarding professional development.

In order to ascertain whether or not the seemingly non-implementors made changes in their teaching strategies, a before and after innovation study is recommended. Mrs. G was in cohort one of two cohorts. The second cohort was the control group for the quantitative study. This group has provided tapes of their class periods which would offer some before and after TI-Navigator™ analysis that I was not privy to this study. These cases may provide more indisputable evidence of teacher change as a result of participation in the CCMS Project and the use of the TI-Navigator™. In future studies of new technology, it is recommended that the non-implementers be a focus of a similar study as well as those who successfully implement the technology.

I hypothesize that a marked difference between cases such as Mrs. G and others who do not appear as interested in changing practices to accommodate student learning is that teachers such as Mrs. G are self-motivated, lifelong learners. Is this the nature of the person? Can a desire for career-long professional development learning be taught? If so, when? And how? To shed some light on this conundrum, it may be interesting to identify a group of pre-service teachers whose program impresses upon them the importance of lifelong learning and supports their doctrine by providing students with self-selected professional development opportunities. Then, follow them through their first five years of teaching, observing the types of professional development opportunities they seek for themselves and the implementation thereof.

Educators may enter their field with a variety of reasons and with a variety of skills. Some are propelled by the visions of a teacher or teachers they desire to emulate, or a passion for their subject matter or a vision of making a difference in this world. While all of these characteristics are admirable, an often-overlooked necessity for effective practitioners is a love of learning. Prospective teachers must leave their pre-service programs armed with a professional development plan of their own design to which they are interested and committed. In-service teachers must respectfully be given a voice and support to pursue their own professional development interests along with those necessary to promote the districts goals. Until the importance that is placed on student achievement is paralleled in teacher learning the cycle of “always reforming by never improving” (Stigler & Heibert, 1999, p. ix) will continue.

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APPENDICES

Appendix A

The CCMS Project

> The research design for this study is a randomized cross-over trial where the control group is exposed to the intervention sequentially. This research design combines the advantage of both a true experimental design with the complete randomized trial during the first year followed by control group teachers receiving treatment during the second year of the study and serving as their own control. This mixed method approach uses quantitative data for statistical analysis as well as qualitative data for in-depth analysis of classroom conditions in connected classrooms (CCMS, 2005).

The CCMS Project focuses on the impact of the connected classroom for mathematics and science achievement and professional development as teachers integrate this new technology into their classroom practice. The quantitative study uses pretests and posttests to measure student achievement gains. The qualitative data includes classroom observations, telephone interviews, post-observation interviews, teacher beliefs and attitudes surveys, student beliefs and attitudes surveys, and student focus groups.

There are multiple parts to the intervention for the CCMS study. Technology for the project includes TI-Navigator ™, a classroom set of graphing calculators and a laptop computer for every classroom during the years of participation in the study. The TI-Navigator ™ is most effectively used with a digital projector so that student responses may be posted for the whole group to view, which aids students in monitoring their own progress. Required professional development for participants includes a week-long training session at The Ohio State University led by Teachers Teaching with Technology (T^3) instructors and follow-up professional development at T^3 International Conferences for the years they are involved in the study. Additional professional development support is provided by on-line training and help as needed, a web-based forum for teachers to share ideas, concerns and questions, as well as experiential learning and experimenting with the software and equipment in teachers' classrooms.

Participant selection

The participants for the project were self-selected. One of the principal investigators attended graphing calculator sessions at the National Council of Teachers of Mathematics annual meeting and announced the possibility of the project. Additionally, he attended the s TI-Navigator™ sessions at the T^3 international conference. Moreover, an email message was sent to teachers using graphing calculators from a list supplied by Texas Instruments to announce the possibility of the project. The email included contact information so that prospective participants could request an application to participate. Prospects then applied to participate. The requirements for being chosen were familiarity with the TI-83 Plus or TI-84 graphing calculator, having only minimal exposure to the TI-Navigator™ , administrative commitment of support to be involved for four years and an agreement to purchase a TI-Navigator™ at a reduced rate and to provide a classroom set of graphing calculators. Chosen participants were also to commit to attend a week-long training session at The Ohio State University where they would receive intensive instruction on the technology as well as on the pedagogical goals of the project, and they agreed to attend the T^3 International Conference annually in conjunction with a CCMS professional development meeting and share session.

Annual responsibilities for the participants include completing a teacher beliefs and attitudes survey; having students complete a student beliefs and attitudes survey; administering pretests and posttests; participating in a fall and a spring telephone interview, and implementing the TI-Navigator™ into their classroom practices. There were initially 127 algebra teacher participants. For feasibility purposes, only 30 were chosen for classroom observation. These were chosen based on geographical convenience, and not based on perceived success or lack thereof. The classroom observation consists of videotaping, a collection of artifacts, a post-observation interview, and a student-focus group interview. The observations are conducted on two, three, or four consecutive instructional days.

Leadership of CCMS

Dr. Douglas Owens, the principal investigator is a professor of mathematics education at The Ohio State University. He is the project director and overall administrator of the grant, assures compliance with research ethics and IRB procedures, and communicates with teachers, the granting agency and Texas Instruments personnel. Dr. Stephen Pape is associate professor of mathematics education at The University of Florida. He gives general direction to the algebra research, to instrument development, and to the classroom observations component based on his previous research. He contributed the theoretical perspective of self-regulated learning. Dr. Karen Irving is assistant professor of science education at The Ohio State University. She gives direction to the science component, telephone interviews for algebra and physical science teachers, and construction of science instruments. From her research interest, she contributed the theory related to formative assessment to the project. Dr. Louis Abrahamson, Better Education Foundation, is an engineer by training and has devoted the last several years to learning and research in mathematics and science. He developed a wired classroom communication system, a precursor to the TI-Navigator™. Contributing to the theoretical framework, he proposed the *How People Learn* centerednesses perspective (National Research Council, 2000) as a rationale appropriate to the learning environment in the presence of the technology. The Ohio State University emeritus professor of mathematics, Dr. Frank Demana, was a co-founder of Teachers Teaching with Technology (T^3), a professional development appendage of Texas Instruments, Inc. (TI). He helped design the professional development, and he aids communication with TI personnel.

Evaluative leadership includes faculty at The Center for Research on Evaluation, Standards, and Student Testing (CRESST) at the University of California, Los Angeles (UCLA). UCLA is a partner for the purpose of research design and data analysis. Dr. Joan Herman, associate director gives general advice on design and documentation. Dr. Christy Kim Boscardin, replaced in February 2008 by Dr. David Silver, provides statistical analysis and research expertise. Test papers go to CRESST for scanning and storing data in the data bases. Dr. Vehbi A. Sanalan, post-doctoral researcher at The Ohio State University, has returned to Erzincan University, his home university in Turkey. Sanalan developed and managed the project website, created appropriate data bases to store various data, helped design the algebra test, telephone interviews and rubrics. Dr. Sanalan was instrumental in creating the Teacher Instructional Practices and Beliefs Survey Web-based instrument, and gave direction to collection and analysis of log files collected by teacher computers while using TI-Navigator™ .

Research Questions of the CCMS study

Research Questions for the CCMS study include:

1. How do teachers' professional development with appropriate pedagogy and the use of the connected classroom TI-Navigator™ system affect student achievement in algebra 1 and physical science?
2. How do teachers' formative assessment and discourse practices change in the TI-Navigator™ connected algebra or physical science classroom?
3. How do these changing formative assessment and discourse practices support the development of self-regulated learning behaviors (e.g., strategic behaviors, metacognitively active stances toward learning, and problem-solving skills) and productive dispositions toward mathematics or science among participants' students?
4. What is the relationship between the pedagogy and technology in TI-Navigator™ connected classrooms? How does the technology supplement or facilitate changing classroom practice?
5. How does use of the connected classroom TI-Navigator™ system support proactive and reactive teacher instructional strategy choices in mathematics and science classroom instruction?
6. How do the effects on instructional practices compare/differ in mathematics and science classrooms?

What teacher knowledge, skills, and dispositions interact with effective use of the TI-Navigator™ system implementation? How does pedagogical content knowledge, content knowledge, and beliefs about mathematics and science influence teachers' implementation of the s TI-Navigator™ system? (CCMS, 2005)

Appendix B

CCMS Algebra Classroom Observation Protocol
Codebook
13-Apr-09

Steps to take when coding the transcripts

A. Set your NVivo program to prompt you for your user profile each time you launch the application. To do this:
    a. On the **Tools** menu, click **Options**. The **Application Options** dialog box is displayed.
    b. In the **General** tab, select **Prompt for user on launch**.
B. Create a journal = documentation of "journey" of the research project as a whole; keep track of when and how insights were gained and ideas developed; ideas associated with project beyond any particular document should be notated within project journal document
    a. While coding create "see also links" from journal to evidence within other documents
    b. Document any changes you feel necessary to the coding protocol & NOTIFY all members of the research team
    c. To create the journal as a memo
        1. Select **Sources > Memo**
        2. **RMB (right mouse button) in List View > New Memo**
        3. Name the journal with first name such as "Stephen's journal"
        4. Journal entries may be coded to a node
    d. Remember that you can not edit a memo (or any document) when coding stripes are turned on
C. To see more nodes and text at the same time: **View > Detail View > Right**
D. Import all transcribed files for an observation—multiple documents of a particular type may be imported at the same time
    a. Make certain using final version of the transcript
    b. Folders within Source – documents of a given document type should be sorted within source folders including:
        1. Classroom observation
        2. Student focus group
        3. Post-observation interview
        4. External files
E. Create cases – unit of analysis is the individual observation
    a. Create participant number as parent node; participant number, time of year, and year as child node within participant number case (e.g., 1001 spring 2006)
    b. All data for a case is coded at each of these levels
        1. Highlight the document in the list of sources

    2. **RMB > Code Sources> Code Sources at existing (or new) node**
  c. Assign attributes to appropriate level at each case level OR import from excel table at a later time (ch. 6)

F. Attach all classroom materials as external documents
  a. Instructional materials (e.g., all classroom handouts/materials)
  b. Classroom layout – a labeled map of the classroom/physical arrangement of context

G. To create nodes – only where necessary – ALL members of the research team must be notified immediately.
  a. Each researcher adds a node to their project which is named just for them, e.g. 'Fiona'. Using this node as the parent (top level node), any new nodes you create can be stored under this parent node and coded to. When projects are merged together, even if two researchers have created child nodes with the same name, these nodes will stay separate and easily identifiable (because their hierarchical names are unique) so coding can be discussed and if required, the node(s) moved into the main node structure
  b. To create nodes without coding
    1. In NODES Navigation View, choose type of node
    2. In the List View area below existing nodes, **RMB > Create Free/Tree/(Other) Node**
  c. To create nodes with coding
    1. Highlight text
    2. **RMB > Code > Code selection at New Node**

H. Coding text to nodes
  a. Select text; **RMB > Code > Code Selection at New Node**
  b. Select text; drag to node
  c. To prevent text from being inadvertently moved, turn on coding stripes/coding density

I. Creating spaces for notations – memo text may be coded to a node so that the link between the text and particular nodes is preserved
  a. Journal – notes about project as a whole (beyond a particular document)
  b. Document linked Memos – for spontaneous thoughts and theoretical ideas for a particular document
    1. To create
      1. Select document or case in List or Detail view
      2. **RMB > Memo Link > Link to New Memo**
  c. Node linked memo – reflective thoughts about the concept or case represented by the node; ideas for further analysis
  d. Annotations – notes that illuminate or reflect on a specific part of the text (seen in a document or node)
  e. See also links – links for a specific point in the text to project items of any kind, or to specific content in memos or other documents
  f. Hyperlinks – links from points within documents or externals to non-project on-line items or websites

Coding text: Successive reviews of the transcripts

A. **(Step 1)** First review of video with transcript
   1. Become familiar with observation
   2. Double space between conversational turns
   3. Single space within a turn
   4. Augment transcript as necessary
   5. Correct mathematical language – only change mathematical spoken language this is not correct (e.g., if minus is substituted for the speaker's "negative")
   6. When more than one teacher, distinguish teachers with T1 & T2
   7. When possible, distinguish between students within a conversational episode with S1, S2, or Ss
   8. Delete any reference to student last name
   9. Indicate technology use in square brackets: Record component, problem posed (when appropriate), and start and finish time for each episode of technology use [QP, 5x(3x^2+5x-7), 5:31:04-5:44:09]; Code to appropriate node for type of technology
   10. Capture time for S-S interaction
   11. ONCE THIS IS COMPLETE, this will become the final transcript. To create a READ ONLY document, open the document properties by RMB on the Source and change the document to READ ONLY. (This will make certain that it is not changed by another coder and then we will be able to merge the documents later to capture coding from two coders.)

B. **(Step 2)** Second review of the video with transcript and Level 1 coding. This may be done initially on hard copy or electronically; KEEP ALL coding notes that you indicate on hard copy

C. **(Step 3)** Third review of video with transcript – review Level 1 coding

D. **(Step 4)** Complete Level 2 ratings from composite values based on Level 1 coding

E. Code sequence
   I. Level 1 [See Updated INVivo nodes]
      a. **Question event variables**
         1. Question directionality – 1. T-S; 2. S-T; 3. S-S
         2. Type of Question – 1. authentic (answer not known); 2. recitation/test/known-answer-questions; 3. Request for help; 4. Technology Related
         3. Level of cognitive load – 1. lower; 2. higher order
         4. Uptake – 1. correct answer; 2. incorrect answer; 3. student comment or question
         5. IRE – 1. IRE; 2. IRERE
         6. Eliciting multiple answers or solutions
      b. **Classroom Procedures**
         7. Classroom management – 1. procedures; 2. technology related; 3. technology problems
         8. Technology Instruction
      c. Classroom discourse indicators
         9. Teacher Talk – non-math-related comments

10. Math Comments – 1. T-S; 2. S-T; 3. S-S
11. Teacher Press for student involvement
12. Teacher Press for elaboration, explanations, justifications
13. Scaffolding – 1. activating prior knowledge; 2. questioning and hints; 3. supporting understanding; 4. modeling; 5. Summarizing
14. Learning Strategies

II. Level 2 Categories: Level 2 categories are rated on a relative presence or absence of evidence for a category across the classroom episodes within the observation (i.e., typically 2 classroom periods).

1. Goal Orientation – 1. performance orientation or 2. mastery orientation
2. Educational foci – 1. Procedures (steps of a procedure); 2. Conceptual Knowledge; 3. Declarative Knowledge; 4. Application; 5. Communication; 6. Evaluation
3. Knowledge construction – 1. Individual vs. 2. group
4. Depth of knowledge
5. How people learn centeredness

Notes:

See www.researchsupport.com.au for detailed guidelines and instructions for efficiently using WORD to prepare documents.

"Data sources can be organized in *sets*, which primarily indicate that these data items belong together in some way. Sources can be in more than one set. Apart from providing a visual reminder of some common feature, sets of documents are used primarily when setting up querries" (p. 56).

Notes here are from Bazeley (2007) *Qualitative Data Analysis with NVivo*. Sage publications.
Background Information—attributes for the classroom observation transcripts

Participant number	Participants are coded as a case. All transcripts from a participant's observation should be coded to the parent participant number case node as well as the appropriate subnode (e.g., 1001 spring 2006).
Characteristics of case	
School Attributes	
School community context	Rural/urban/suburban
Percent free/reduced lunch	Quartiles: 0-25%, 26-50%; 51-75%; 76-100%

Percent minority	Quartiles: 0-25%; 26-50%; 51-75%; 76-100%
Achievement	Mean score at class level
Teacher attributes	
Teacher Gender	Male/female
Years teaching experience	1-3 yrs; 4-6 yrs; 7-10 yrs; 10-20 yrs; >20 yrs
Undergraduate degree	Mathematics major; education major; other?
Education degree	None/Elementary/Secondary
Teacher beliefs about mathematics	Levels from survey data
Observation-level attributes	
Characteristics for observation	
Date of observation	Translated into time of year – fall or spring
Technology use year	Participant's technology use year: 1st, 2nd, 3rd, 4th
Observation duration	30, 45, 60, 90, 100 minutes; mixed 45/90 minutes
Classroom characteristics	
Classroom layout	Traditional rows/groups/other descriptions
Content of observed class	Symbol manipulation; graphing linear equations; quadratic equations; etc.

Note times for technology use and S-S interaction during initial viewing of the video.

01. Technology use: For each of the categories of technology use, two ratings will be calculated (a) number of occurrences of technology component use and (b) consistency of technology component use = percentage of time of technology component use (this will need to be calculated following coding of the transcript).

Indicate technology use in square brackets: Record component, problem posed (when appropriate), and start and finish time for each episode of technology use [QP, 5x(3x^2+5x-7), 5:31:04-5:44:09]. Code to appropriate node for type of technology.

An episode of technology use is defined by

a. Shifts in content
b. Indication of shift may be an extended interval when technology is not in use
c. Technology component use as ongoing is indicated by use for a similar topic.

(1) Activity Center; (2) Quick poll; (3) Screen capture; (4) Learn check; (5) TI Presenter; (6) TI viewscreen; (7) Graphing Calculator Use (Use of the calculator as a tool separate from the classroom connectivity technology. This category does not include using graphing calculator solely as a response tool with TI Navigator such as data transmission and submission via the Navigator.); (8) Probeware; (9) Smartboard

02. S-S Interaction: Capture time for group interactions.

Indicate S-S interaction in square brackets by recording start and finish time for each episode [5:31:04-5:44:09]. Code to appropriate node.

Question event variables

Classroom Questions related to mathematics content
03. Question directionality: Who asked the question to whom? Three levels: (1) T-S; (2) S-T; (3) S-S When same question is repeated, only code the question once AND code the most complete question.
04. Type of Question – Four Categories: (1) Authentic: open-ended; no pre-specified answer by question source; requests for information as well as open-ended questions with indeterminate answers; allows range of responses (e.g., How did you figure that out? How did you think about that solution?) (2) Recitation/test/known-answer questions (Nystrand et al., 2003): questions for which prescripted answers are known by question source (3) Request for help: typically voiced by students to teacher but could also be a request to a fellow student

(4) Technology-related: Questions related to the technology (e.g., How do you type that into the calculator?)

05. Level of cognitive load – Categories: (1) Lower vs. (2) higher cognitive load;

Refers to the cognitive load elicited by the question vs. the level of the question itself. When coding questions, context of the question is taken into consideration. That is, consider the level of student response allowed by the teacher. Nystrand (2003): consider antecedents and consequences as they affect inertia of the discourse.

Lower cognitive load questions elicit recalling and stating information or known facts; carrying out a simple algorithm, math procedure, or problem solving steps to complete a task. Rules as justification for an answer are generally considered LO.

Within a series of questions, the initial question may be considered a lower order question, BUT follow-up questions request further elaboration, explanation with justification, etc. For this category instances of lower order questions should be considered separate from these subsequent requests, which may be considered evidence of higher order questions.

POTENTIAL categories of lower-order questions include: procedural questions, requests for recall of know facts, and comprehension questions (see details of each below). BUT response is what is key to coding this category.

a) **Procedural questions:** Request for students to ***communicate the procedures*** used to complete a task such as solving a problem. Requests for explanation of the steps used to solve a problem BUT not a justification or rationale for these steps based on mathematical knowledge.

   Responses to procedural questions involve explanations of steps taken without justifications for why these steps work or why they are allowed mathematically.

b) **Knowledge questions: *Knowledge*** of terminology, specific facts, ways and means of dealing with specifics, conventions, trends and sequences.

   Requests for recall of previously learned material (e.g., definitions, concepts, principles, formulas).
   - What is the definition of parallel lines?
   - What is the sum of the angle measures in a quadrilateral?

c) **Comprehension questions: *Comprehension*** in translation, interpretation, and extrapolation.

   Understanding the meaning of remembered material, usually demonstrated by explaining in one's own words or citing examples.
   - What are examples of parallel lines within our classroom?

- What does point A on the graph on page 19 indicate?

Higher order cognitive load questions elicit responses that may involve manipulation of information and ideas in ways that transform their meaning and implications—combining facts and ideas to synthesize, generalize, explain, hypothesize, or arrive at some conclusion or interpretation. This is predominantly the impact of classroom norms and what is an acceptable answer (i.e., norms for explanations and justifications).

Higher-order questions elicit justifications based on mathematics, classification and categorization, comparison and contrast, exploration of contexts and discussion extended beyond a familiar case; *Application* of concepts; ***Analysis*** of elements, relationships, and organizational principles; Synthesis of ideas in the production of unique communications and plans; ***Evaluation*** leading to judgments.

a) ***Justification*** questions request justification/rationale for steps taken to solve a problem/complete mathematical computation.

b) ***Classification and categorization*** questions request classification and categorization of concepts and principles
   - Classify lines as parallel and perpendicular lines; relationship between equations of each type of lines

c) ***Comparison and contrast*** questions request comparison and contrast of concepts
   - Compare slope of parallel and perpendicular lines
   - Compare slope of vertical and horizontal lines

d) ***Exploration/extension*** questions request exploration of contexts and extended discussion further and further from a familiar case.

e) ***Application*** questions require the application of concepts or skills to particular concrete or real-world situations.
   Using information in a new context to solve a problem, to answer a question, or to perform another task. The information used may be rules, principles, formulas, theories, concepts, or procedures.
   - Using the procedures we have discussed, how would you solve this new problem?
   - How might we use what we learned from X to solve y?
   - Based on your knowledge, what statistical procedure is appropriate for this problem?

f) ***Analysis*** questions require the analysis of elements, relationships, and organizational principles. Breaking a piece of material into its parts and explaining the relationship between the parts.
   - In the solution to problem X, what mathematical rules did we use to solve the problem?
   - What is the relationship of probability to statistical analysis?

g) ***Synthesis*** questions require the synthesis of ideas in the production of unique communications and plans. Putting parts together to form a new whole, pattern or structure.

- Let's think about these two previous problems. What are the steps you used in these problems that will help us to solve this new problem?
- How would you proceed if you were going to do an experiment on caloric intake?

h) ***Evaluation*** questions require the evaluation leading to judgments about the value of materials and methods for given purposes. Using a set of criteria, established by the student or specified by the instructor, to arrive at a reasoned judgment.

- How was the solution to problem X different from/similar to the solution to problem Y?
- How was student X's solution different from/similar to student Y's solution?
- Which of these strategies for solving the problems is more efficient?

06. Uptake of correct and incorrect responses – Categories: (1) correct answer, (2) incorrect answer, or (3) student comment or question

Uptake of correct and incorrect responses refers to the degree to which and ways in which the teacher "takes up" (i.e., explores, engages with, discusses, critiques, reasons about, provides rationale to support) correct and incorrect responses as objects of classroom discourse. Uptake involves classroom discourse (or teacher press) that immediately follows a student response (via TI Navigator or oral responses). It is coded beginning with the first statement (the uptake) following the statement (response or mathematical comment) that is the object of the uptake.

Occurs when an individual asks someone about something the other person said previously. May be noted by the pronouns (dietic reference) that refer back to the original statement and "makes the [original] response the momentary topic of discourse…. Uptake may play an important role in facilitating the negotiation of understandings, as conversants listen and respond to each other. Moreover, by building on the voices of others and by establishing intertextual links among speakers, uptake acts to promote coherence within the discourse" (Nystrand, et al., 2003, p. 146).

Uptake must reference previous response. Repeated questions are not considered uptake. Uptake disrupts IRE pattern.

Code entire episode of uptake – uptake episode consists of discourse that holds a previous response [that is taken up] as an object of discourse; thus an episode is defined starting with the "uptaker's" (typically the teacher's) initial statement referring to the previous response until the topic of the response changes to a new topic (i.e., there is a change in the discussion topic; a break in the conversation).

07. Initiation-Response Evaluation (I-R-E)—There are two sub-categories:

(1) IRE is typically a 3-conversational turn sequence during which (a) the teacher initiates by asking a question, (b) a student responds, and (c) the teacher evaluates the student's response;

(2) IRERE (or IRERERE) typically occurs when the first student's response is not correct leading to additional responses being solicited and an (a final) evaluation is made when the correct response is provided. An episode of the extended IRE sequence would typically consist of 5, 7, 9, … conversational turns.

Evaluative statements made by the teacher may be implicit as evidenced by affirming a student's response by repeating it.

Examples:

- T: "What is the reciprocal of 34/56ths?" S: "56/34ths. T: "Very good!"
- T: "What is the answer to number thirteen?" S: "15" T: "Not exactly. Someone else?"

08. Eliciting multiple answers or solution methods: Multiple answers or solutions may be implicitly or explicitly elicited by the teacher. Context needs to be considered especially when elicitations are implicit. In these cases, the students' responses should be used to determine whether the teacher's statement should be coded as eliciting multiple answers or solutions. An explicit teacher request for additional answers or solutions should be coded to this node regardless of student response.

Teacher saying … "anyone else have a different response" … constitutes an elicitation regardless of the students' response.

Evidence of practice might include (1) listing all responses to a question; (2) this list is the vehicle for exploring the problem and understanding concepts – the class is engaged in a discussion of the different responses. The teacher ultimately determines how the various responses are taken up by the class.

Classroom Procedures

09. Classroom Management: Three categories: (1) Procedures, (2) Technology related, (3) Technology problems

Giving directions and directives or asking questions relative to implementing classroom procedures OR use of technology (i.e., telling children that they are to use the technology NOT instruction on HOW to use the technology); reminders of how students should act or the procedures for classroom tasks; reminders of class routines; telling students how to act and think.

(1) Procedures – also includes statements that reflect procedural aspects of the classroom that are NOT directives such as questions, taking attendance, etc.

- "Just listen and write down what I say."
- "Write this on your paper; it's simply memorizing the pattern."
- "You need to pay attention." "Take out your books and number your papers from 1 to 25."
- "Is there a reason you're not in your assigned seat?"
- Are you logged into the Navigator?

(2) Technology related—directives for the student to do something on their calculator (or Navigator).

- Let's all put $y = 3x + 5$ into our y1.
- You can send the answer whenever you're ready.

(3) Technology problems

10. Technology instruction: Step-by-step directions related to how to use the technology.

Classroom discourse indicators

11. Teacher Talk—not mathematics related teacher statements

All teacher talk that is not strictly math-content related.

Teacher questions that are not math related should be coded as Teacher Talk. ➢ How are we doing? ➢ Does that make sense to everybody? ➢ Did you have a question?
12. Math comments—There are three categories: (1) T-S; (2) S-T; and (3) S-S All mathematics statements <u>regardless of other codes applied</u>. Including teacher lecture about math content or student math-related comments including all student-teacher math comments that are direct responses to a teacher question. Individual student responses should be coded as separate episodes.
13. Teacher press for student involvement: General category related to code teacher strategies for increasing involvement of all students. ➢ Teacher may use Quick Poll to increase student engagement in the lesson ➢ Teacher discourse implicitly or explicitly presses students for involvement ➢ Teacher use of questions to elicit mathematics concepts from students versus teacher telling students the mathematics they should learn. (This teacher questioning may also be coded as scaffolding.)
14. Teacher press for elaboration; explanations, justifications: Teacher presses students to elaborate their ideas or to make their reasoning explicit. Teacher follows students' answers with a request for deeper thinking. Students' responses are followed by a teacher's (or another student's) question such as: ➢ How do you know that? ➢ How else might we explain this idea? ➢ Does anyone disagree with this answer and why?
15. Scaffolding: Scaffolding is social support for student achievement. Categories include: (1) Activating prior knowledge: [Do NOT consider questions about whether students remember something such as, "You took a quiz on Thursday, do you remember it" as activating prior knowledge.]; (2) Questioning and hints: Teacher hints, cueing questions (What would you do next?), or providing essential elements to support solution/understanding (VERSUS telling); Scaffolding can not consist of one single question BUT must be a series of questions designed to support a student who typically originally provided an incorrect answer OR is not able to state a response to a teacher questions; (3) Supporting understanding: for example, elaboration of procedure; "making thinking visible"; Re-voicing -- re-describing student contributions to a discussion in more precise mathematical terms. (4) Modeling: Teacher modeling a way to think about a problem, a strategy, or a

solution.

(5) Summarizing

16. Learning strategies: Episodes that make learning strategies (i.e., ways of learning or strategies to learn the mathematics) an object of discourse in the classroom. This may be done implicitly or explicitly. These discussions are typically distinct from discussions of mathematics content.

Teacher support for metacognitive activity. Learning strategies are evident when (1) the teacher or another student models their thinking while solving a problem; (2) modeling (explaining while performing the steps for students to follow) a procedure. Providing reasoning about the mathematical steps supports strategic methods for remembering the procedure.

Learning strategies are a central feature of a classroom in which thinking is raised to the level of explicitness so that it becomes an object of examination within the class. That is, evidence for a context that supports learning strategies is when thinking or how an individual thought about a solution or concept is examined within classroom discourse. Evidence must include explicit attention to strategies or ways of going about learning. Simply modeling the steps of a procedure should be coded to "teacher talk" node.

17. Dialogic Episode: Dialogic episodes occur when participants in classroom discourse exchange ideas in a nonprescripted way, expanding on or modifying the contributions of others, resulting in sustained discourse about mathematical ideas. Dialogic episodes are characterized by engaged student questions and the absence of recitation questions from the teacher, although recitation type questions may be used to maintain the impetus of the conversation.

Teachers may draw students into dialogic discourse with "dialogic bids" (Nystrand et al., 2003). Specific types of teacher and student moves might lead to dialogic discourse, such as use of authentic questions, teacher uptake of students' comments and questions, or student observations and questions. Teacher questions may be strategically aimed at drawing students into discourse based on products of student work, such as incorrect or correct answers, to deepen their understanding of the thinking that led to such an answer. The teacher's role is to keep the discussion going while the students make substantive contributions in the form of observations, conjectures, argumentation, and reasoning.

18. Goal orientation—There are three subcategories: (a) Performance orientation; (b) Mastery orientation

(a) Performance orientation: is evidenced by a focus on the outcomes/products; focus on showing competence. Instructional orientation is focused on obtaining correct answers. Thus, instruction focused on mathematical procedures with the expressed or implicit goal of learning the procedure so that students can get the right answer is evidence of a performance orientation. Focusing on grades and assessments as the motivation for learning mathematics.

Examples include:

- References to everyone "getting it perfect";
- References to whether material was "hard" or "easy" to "get right";
- Focus on doing math with purpose of getting the right answer;
- References to being the TRICKY teacher who poses problems to trick students;
- References to extrinsic rewards – e.g., candy – for getting problems correct (vs. giving extrinsic rewards for understanding mathematics)
- Reference to plugging numbers into the calculator rather than understanding the mathematics.

(b) Mastery orientation is evidenced by a focus on understanding the procedures used to solve problems and a focus on learning skills. A mastery orientation is related to incremental views of intelligence that hold intelligence to be malleable and developed through appropriate and challenging experiences.

➢ Focus is on understanding why a process works versus how it "gets" the right answer.
➢ Classrooms may support a mastery orientation by limiting the emphasis on grades as outcomes and increasing the focus on learning through assessments.

Level 2 Categories:
Level 2 categories are rated on a relative presence or absence of evidence for a category across the classroom episodes within the observation (i.e., typically 2 classroom periods). NEED TO DETERMINE WHETHER THESE ARE COMPOSITE VARIABLES OR ATTRIBUTES FOR A CASE.

1. **Technology use consistency—**Code the consistency of technology use that is NOT Navigator related.

0 = No technology used
1 = Minimally present
2 = Somewhat present – not a consistent feature of the classroom instruction
3 = Consistent feature of classroom instruction

2. **Navigator Technology use consistency**—Code the consistency of Navigator technology use.

0 = No technology used
1 = Minimally present
2 = Somewhat present – not a consistent feature of the classroom instruction
3 = Consistent feature of classroom instruction

3. **Goal orientation—**There are three subcategories: (a) Performance orientation; (b) Mastery orientation

Rating:
1 = focus is a performance orientation;
2 = mixed;

3 = focus is a mastery orientation

(1) Performance orientation: is evidenced by a focus on the outcomes/products; focus on showing competence. Instructional orientation is focused on obtaining correct answers. Thus, instruction focused on mathematical procedures with the expressed or implicit goal of learning the procedure so that students can get the right answer is evidence of a performance orientation. Focusing on grades and assessments as the motivation for learning mathematics.

Examples include:

- References to everyone "getting it perfect";
- References to whether material was "hard" or "easy" to "get right";
- Focus on doing math with purpose of getting the right answer;
- References to being the TRICKY teacher who poses problems to trick students;
- References to extrinsic rewards – e.g., candy – for getting problems correct (vs. giving extrinsic rewards for understanding mathematics)
- Reference to plugging numbers into the calculator rather than understanding the mathematics.

(2) Mastery orientation is evidenced by a focus on understanding the procedures used to solve problems and a focus on learning skills. A mastery orientation is related to incremental views of intelligence that hold intelligence to be malleable and developed through appropriate and challenging experiences.

➢ Focus is on understanding why a process works versus how it "gets" the right answer.

➢ Classrooms may support a mastery orientation by limiting the emphasis on grades as outcomes and increasing the focus on learning through assessments.

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4. **Educational Foci**: Indicate the degree to which the classroom evidences each of the types of foci.

Rating scale: Rating scale for these categories
0 = not present;
1 = minimally present;
2 = somewhat present – not a consistent feature of classroom instruction (i.e., only occurred at one
point or for a short duration);
3 = consistent feature of the instruction (i.e., clearly evident throughout the class; occurs regularly
throughout the instruction)

There are 6 subcategories: (1) procedural knowledge; (2) conceptual knowledge; (3) declarative knowledge; (4) Application; (5) Communication; (6) Evaluation.

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(1) Procedural Knowledge: Focus on the STEPS of a procedure without understanding.

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(2) Conceptual Knowledge: Teacher instructional practices indicate a goal that

students should know and understand conceptual foundations of procedures. Teaching students why a procedure works would be evidence for this category.
(3) Declarative Knowledge: A focus on definitions, names of theorems, rules, and facts.
(4) Application: Teacher instructional practices indicate a goal that student should know how to apply what they learn to analyze situation and solve problems.
(5) Communication: Teacher instructional practices indicate a goal that students should be able to communicate what they know to others. Consistent requests for explanations and justifications would be an indicator of a focus on communication.
(6) Evaluation: Teacher instructional practices indicate a goal that students should be able to evaluate critically the usefulness of various problem-solving approaches.
5. **Knowledge construction:** Indicate the degree to which knowledge is individually versus group constructed. **Rating:** 1 = individual knowledge construction; 2 = mixed; 3 = group knowledge construction Individual knowledge construction might be characterized as teacher centered, students experience limited opportunities to learn within social interaction; teacher does the work to explain a concept (perhaps predominantly lecture format) and students are left to construct an understanding of the concept largely as individuals. The community does not support social interaction as a critical factor in learning. Group constructed knowledge might result from activity that incorporated some small-group investigation. Critical to group construction is the ways in which the mathematical concepts are made explicit for students within the whole class discussions.
6. Depth of Knowledge: Indicate the degree to which knowledge is thin/superficial or deep/connected. **Rating:** 1 = "thin" or superficial knowledge; 2 = some exploration of ideas to deepen knowledge and support limited connections between concepts; 3 = understanding and deep knowledge supported by strong understanding of interrelationships of mathematical concepts "Knowledge is thin or superficial when it does not deal with significant concepts of a topic or discipline. Knowledge is deep or thick when it concerns the central ideas of a topic or discipline." (Newman & Wehlag, 1993, p.9). Descriptors from Kitchen, DePree, Celedon-Pattichis, & Brinkerhoff (2007). *Mathematics education at highly effective schools that serve the poor: Strategies for*

change. Mahwah, NJ: Lawrence Erlbaum.
Below is quoted from pages 175-176. Categories 1 & 2 would result in a rating of 1; Category 3 would result in a rating of 2; categories 3 & 4 would result in a rating of 3.

1. Knowledge is very thin because concepts are treated trivially or presented as nonproblematic; students are involved n the coverage of information they are to remember.
2. Knowledge remains superficial and fragmented. Underlying or related concepts and ideas might be mentioned or covered, but only a superficial acquaintance or trivialized understanding of these ideas is evident.
3. Knowledge is treated unevenly during instruction; deep understanding of some mathematical concepts is countered by superficial understanding of some other ideas. As least one idea may be presented in-depth and its significance grasped by some (10%-20%) students, but in general the focus is not sustained.
4. Knowledge is relatively deep because the students provide information, arguments, or reasoning that demonstrates the complexity of one or more ideas. The teacher structures the lesson so that many students (20%-50%) do at least one of the following: sustain a focus on a significant topic for a period of time; or demonstrate their understanding of the problematic nature of information and/or ideas; or demonstrate understanding by arriving at a reasoned, supported conclusion; or explain how they solved a relatively complex problem.
5. Knowledge is very deep because the teacher successfully structures the lesson so that most students (50%-90%) do at least one of the following: sustain a focus on a significant topic; of demonstrate their understanding of the problematic nature of information and/or ideas; or demonstrate understanding of complex understanding by arriving at a reasoned, supported conclusion; or explain how they solved a complex problem. In general, students' reasoning, explanations, and arguments demonstrate fullness and complexity of understanding.

7. Student discussion of understanding

Student communication of evolving understanding; opportunities for students to express their understanding; instruction provided opportunity for individuals or groups of students to negotiate (shared and individual) understandings. Understanding concepts and procedures through interactive discussion is central to the instructional context of the class.

Ratings adapted from Kitchen, DePree, Celedon-Pattichis, & Brinkerhoff (2007). *Mathematics education at highly effective schools that serve the poor: Strategies for change.* Mahwah, NJ: Lawrence Erlbaum.
Below is quoted from pages 178.

0. Virtually no features of mathematical discourse and communication occur, or what occurs is of a fill-in-the-blank nature.
1. Sharing and the development of collective understanding among a few students (or between a single student and the teacher) occur briefly.
2. There is at least one sustained episode of sharing and developing collective understanding about mathematics that involves: (a) a small group of students or (b) a small group of students and the teacher. Or, brief episodes of sharing and developing collective understandings occur sporadically throughout the lesson.

3. There are many sustained episodes of sharing and developing collective understandings about mathematics in which many students (20%-50%) participate.
4. The creation and maintenance of collective understandings permeates the entire lesson. This could include the use of a common terminology of meanings. Most students (50%-90%) participate.

06. How People Learn: Indicate the degree to which the classroom evidences each of the type of centeredness constructs.

Rating scale:
0 = not present;
1 = minimally present;
2 = somewhat present – not a consistent feature of classroom instruction (i.e., only occurred at one point or for a short duration);
3 = consistent feature of the instruction (i.e., clearly evident throughout the class; occurs regularly throughout the instruction)

(1) Learner-centered: According to HPL, "learner-centered" refers to environments that pay careful attention to the knowledge, skills, attitudes, and beliefs that learners bring to the educational setting. This term includes teaching practices that:

- build on the conceptual and cultural knowledge that students bring with them to the classroom by,
  - helping students make connections between their previous knowledge and their current academic tasks;
  - identifying students' knowledge, interests, and passions;
  - incorporating students' home and community cultural practices and language use;
  - connecting everyday talk with school talk;
- fit the concept of "diagnostic teaching" by,
  - attempting to discover what students think in relation to the problems on hand;
  - challenging and discussing students' misconceptions sensitively;
  - giving students situations (critical tasks) to go on thinking about which will enable them to readjust their ideas;
  - prompting students to explain and develop their knowledge structures by asking them to make predictions about various situations and explain their reasoning for their predictions;
  - discussing conflicting viewpoints; and,
- have been called "culturally responsive," "culturally appropriate," "culturally compatible," and "culturally relevant."
- Provides an active learning experience that,
  - engages students;
  - lends appropriate pressure for students think through issues, establish positions, and commit to positions;
  - makes student's thinking visible;
  - encourages reflection and self-assessment on what worked and what needs improving;
  - teaches metacognition and self-regulation.

(2) Assessment-centered: The key principles of assessment are that they should provide opportunities for feedback and revision and that what is assessed must be congruent with one's learning goals. HPL lists teaching practices in assessment-centered environments as those which:

- utilize both formative and summative assessment,
- focus on understanding, not memory for procedures or facts;
- provide continuous feedback as part of instruction;
- monitor both group work and individual performances;
- help students build skills of self- and peer-assessment;
- provide students with opportunities to use assessments to revise their thinking;
- help teachers rethink their teaching practices.

(3) Knowledge-centered: HPL terms teaching practices in knowledge-centered environments, as those which:

- take seriously the need to help students become knowledgeable by learning in ways that lead to understanding;
- focus on the kinds of information and activities that help students develop an understanding by,
    - critically examining existing curricula;
    - considering depth vs. breadth of content covered;
- include an emphasis on sense-making—on helping students become meta-cognitive by expecting new information to make sense and asking for clarification when it doesn't;
- fit the concept of "progressive formalization" by,
    - beginning with informal ideas that students bring to school and gradually help them see how these ideas can be transformed and formalized;
    - moving from students' own words to standard conventional language and notation after they have had sufficient experience with underlying concepts;
    - questioning what is developmentally appropriate to teach at various ages;
- foster an integrated understanding or overall picture of the discipline (e.g. mathematics) instead of skills in isolated pieces by,
    - structuring activities so that students are able to explore, explain, extend, and evaluate their progress;
    - striking the appropriate balance between activities designed to promote understanding and those designed to promote the automaticity of skills necessary to function effectively.

(4) Community-centered: In HPL, "Community centered" refers to several aspects of community, including the classroom as a community, the school as a community, and the degree to which students, teachers, and administrators feel connected to the larger community of homes, businesses, states, the nation, and even the world.

- value the search for understanding;
- value high standards for learning;
- allow students and teachers the freedom to make mistakes in order to learn;
- do not hinder students' willingness to ask questions when they do not

understand the material;

- explore new questions or hypotheses;
- convey expectations for school success for all students;
- are sensitive to modes of participation and levels of competition that may be unfamiliar to students;
- connects what is learned in school to out-of-school learning and vice versa.

VITA

Sharilyn K. Owens was born in Georgia in 1966 to parents who were strong advocates of public education. After growing up in Vancouver, British Columbia, Sharilyn returned to Georgia to attend the University of Georgia for her B.S.Ed. (1988) and M.Ed. (1992). After teaching for one year at Fort Valley Middle School, Sharilyn returned to her roots for a mathematics teaching position at Macon County High School, where her father taught mathematics the year she was born!

Sharilyn has taught Spanish in a K-5 setting, middle school, high school and college level mathematics. She has taught students ages 4 to 72. She currently shares her schedule between Wilkes Community College where she teaches in the mathematics department and Appalachian State University where she teaches pre-service elementary teachers in the college of education.

Sharilyn hopes to influence the professional development programs available to practitioners and pre-service teachers. She also has a special interest in meeting the educational needs of rural students in a poverty cycle.